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TRANSACTIONS

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OF THE

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TORONTO

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96743
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1904

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PREFACE.

It is with pleasure we offer the seventeenth volume of the Transactions of the Engineering Society of the School of Practical Science. In it we present a considerable number of the papers read before the members during the session of 1903-1904.

The papers were received with great interest. Certain of them treat subjects which have not been dealt with before in the Transactions, such being specially welcome additions to the already long index to this and the preceding sixteen numbers printed on pages 184 to 190. Where illustrations add to the clearness and value of the text, they have been very liberally supplied.

The preceding edition of 1,500 copies was found too small, owing partly to increasing membership and partly to an increasing demand from other engineering colleges for exchanges. To supply this demand, the present edition consists of 1,900 copies. A list of exchanges will be found elsewhere.

The Society wishes to tender its hearty thanks to all contributors.

Toronto, April 12, 1904.

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Zimmer, A. R., 06.

THE LATE PROFESSOR E. J. CHAPMAN

Who was one of our honorary members ; from a photo in his own lecture room, by Dr. W. H. Ellis.

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OBITUARY NOTICE.

THE LATE PROFESSOR E. J. CHAPMAN.

By W. H. Ellis, M.A., M.B.

In Professor E. J. Chapman—the news of whose death, on the 28th of January last, at the ripe age of eighty-three, has just reached us—we have lost one who, for more than forty years, was a notable and honoured figure in the life of our University. A sketch of his life, from facts supplied by himself, appeared in the issue of the University of Toronto Monthly for June, 1902, under the signature of the present writer.

It only remains here to record the personal impressions resulting from an acquaintance and friendship of thirty years' duration, and to express the feelings of affection and esteem which Professor Chapman evoked in all who were brought into contact with him, whether as students or colleagues.

Educated in France, he joined the army of Algiers as a volunteer. There he took part in several important engagements, and was severely wounded. Returning to England, he studied Civil Engineering, became Professor of Mineralogy in University College, London, and was appointed to the chair of Mineralogy and Geology in Toronto, in 1853, being then thirty-two years of age.

Tall and erect, his figure never lost the military bearing acquired in early youth. He was an expert fencer, and he used to describe with much enjoyment a bout with the foils between himself and Prince Louis Napoleon, afterwards Napoleon III., which took place at the London Fencing Club. He was an accomplished amateur actor, and on the occasion of a dispute between the late Mr. Fechter and some of his company, during the performance of Hamlet in Toronto, he offered, on the spur of the moment, to take the part of Laertes. It has been a lasting regret to many of those present that his offer was not

accepted. He was a charming *raconteur*, accompanying his narration with great vivacity of voice and gesture. His manner was polished to a degree; and his cheerful and genial simplicity made him a most delightful companion.

His knowledge of Mineralogy was deep and wide, and he was an expert master of the use of the blowpipe as an aid to the determination of minerals. As a teacher, he was unsurpassed in the ability of imparting clearly and impressively the instruction which he wished to convey. But his success as a University professor was somewhat hampered by an abiding distrust of the capacity of his students.

He was the author of several elementary text-books on his subject, as well as of various scientific papers. But he did not confine his literary efforts to such themes as these. His reading was wide and varied, and his taste excellent. Several poems, published at different periods of his life, bear testimony to the many-sidedness of his character. He was a man of the nicest sense of honour, and always endeavoured to act in accordance with his convictions, no matter what the consequence might be.

I once heard one of his colleagues pay him what I then thought, and think still, one of the highest possible compliments. During a passing storm in the Academic tea-pot, when party spirit was running high, we were endeavouring to forecast the result of a coming vote. "There is no counting on Chapman," said my friend. "He'll vote as he thinks right."

I may, perhaps, be permitted to conclude this imperfect sketch of a striking personality with the following incident, related without comment as I heard it from his own lips, shortly after the occurrence.

On entering his bedroom one evening, about dusk, he thought he saw his mother, who was then at an advanced age, sitting up in bed, wrapped in a little India shawl which he knew well, but which he had never seen her wear. The shawl had been given to her by a relative who had died in India. Her children, when dressing for char-

ades, had often coveted it, but were never allowed to touch it. He spoke to her, but as he spoke the vision faded. He attributed the phenomenon to some disorder of vision produced by temporary indisposition, but he was unable for some days to shake off the feeling of apprehension caused by the incident. The next English mail, however, brought him a cheerful letter from his mother, telling him that her health had been unusually good, and discussing pleasantly some books she had been reading. He dismissed the occurrence from his mind; but the next mail brought the news of her death at an hour coinciding with that at which he had seen her image. On enquiry, he learned that for several months before her death she had taken to using the shawl in question, and that she was wearing it when she died.

I have just been favoured by the kindness of Mrs. Chapman with a copy of Professor Chapman's last publication, bearing the date 1904, the preface of which was written at his house, "The Pines," Hampton Wick, in September last. It is entitled "Mineral Systems: A Review, with an outline of an attempted Classification of Minerals in Natural Groups." The book is a vigorous protest against the classification of minerals on chemical grounds alone, and an argument for one based upon mineralogical characters. It is written with all his old clearness and force, and forms a fitting conclusion to the labours of a long and useful life.

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ENGINEERING SOCIETY

OF

The School of Practical Science

TORONTO.

PRESIDENT'S ADDRESS.

GENTLEMEN:—

It is with great pleasure at this the first meeting of our Engineering Society that I thank you for the confidence you have reposed in me by electing me to this position. During former years this Society has been presided over by able men under whom it has made great progress, so that year by year its influence on our student life is increased. This year our membership is larger than ever before, reaching as it does to over four hundred. It is therefore with some diffidence on my behalf that I accept a position fraught with so many responsibilities.

I have also to thank you for the energetic committee you have elected to my aid. We together shall endeavor to continue the progress which has so characterized the history of the Society, and to this end we ask from every member his most hearty co-operation.

To the gentlemen of the first year I extend a very hearty welcome. If you would reap the greatest benefits do not wait until your senior years to enter into the working life of the Society, but realize at once that these meetings are for the benefit of every student of the School, and it requires the support of every member to make them a success.

In regard to the relation between this Society and the School itself, let me say that our meetings are a part of the work of this institution, and are regarded as such by the faculty as long as a part of the working day is devoted to them. And let me impress on you, gentlemen, that our work here as members of the Society is not the least important factor in our course, and that these meetings should be attended as faithfully as your lectures.

The purpose of this Society is to encourage the investigation of engineering subjects; to disseminate this knowledge among its members, and to cultivate a spirit of mutual assistance. When a paper therefore is to be read before the Society, prepare questions to ask on the subject, and be ready to discuss points of interest or doubt that the speaker may or may not bring forth. You will thus greatly benefit yourself and interest and enlighten other members who have not the same knowledge of that particular subject.

As I have mentioned at a former time, it is nearly impossible to always present papers which will have the same interest to all years and classes of this student body. Though members of one engineering college, yet we represent all the different branches of engineering and all the different years of study for each branch. But your committee will do their utmost to select subjects which will be of general interest, and whenever we depart from the ordinary mode of procedure it will be with the object of benefiting each student and the Society in general.

I would ask you all therefore to take an interest in everything pertaining to the advancement of our Society; prepare a paper if you can; or if you know of any who would be willing to contribute a paper which you would like to hear, kindly let us know and we will endeavor to arrange for it. Do not leave either of these off until too late, because the number of our meetings is limited and they cannot all be held during the last term, therefore kindly inform your committee as soon as possible, and thus make it easier for us and more beneficial to the whole Society.

There are several matters of importance to us as students of the School of Practical Science and Faculty of Engineering and Applied Science of the University of Toronto of which I might speak. Some of these have been dealt with by former presidents, and I would refer you to them, but I would like to speak here of some others.

Allow me to say for the benefit of the gentlemen of the first year, that last year we decided on a design for a School of Practical Science pin. It is not only a college pin by which we can at once recognize each other around the University, or when away in our field work, but it is also a class pin, as on it are two raised figures giving the year your class will graduate. This pin is manufactured for us in three qualities by Ambrose Kent & Co., and can be bought only through the Engineering Society. You may leave your orders with the librarian and they will be promptly filled. It is hoped that every student of the school may purchase one, and that each graduate of former years may send for one that he may be known by those following.

The new Science Building for which we have all been eagerly waiting is rising surely if slowly. Next year we hope may see it completed, so that our growing classes may have all the room necessary for the most efficient work. It is being built on the most approved plans and will furnish classes in engineering with all conveniences necessary for the carrying on of their work.

We are all glad to learn that our University is growing in other departments. Trinity Medical College has confederated with the Toronto Medical Faculty, and the new Medical Building which has just been completed is none too large for the augmented classes.

Need I speak to you of athletics? Who has not heard of the achievements of the S. P. S. in that direction. The School has almost became the storeroom for all the trophies offered by the University; in fact last year we were looking around for "other worlds to conquer," as our association football teams played for the championships of Ontario. To continue the record of the past is about all we can expect, and surely none could ask more. Did I hear some one say we are losing our grasp on the trophies this year; well, we may have to let some of them go, just to make room for the students, but "school cups" will surely all shine again in the new building.

While thinking of different subjects on which to speak to you, it seemed I could not do better than say a few words on the tendency of engineering.

The great numbers of students thronging to our engineering colleges make us inquire to what is the profession advancing. Is it to an overcrowded state where all are clamoring for employment

and one man is crowding his neighbor down to idleness and poverty, or is this throng the natural outcome of a country awakening to her greater possibilities and calling upon her sons to prepare themselves for the great work of advancement? We still hope it is the latter, and hope we think not without reason, as it is the work of the engineer to direct the great powers of nature for the use and convenience of man while the experience of every day shows that there are sources of power not fully developed, that there are problems of nature not yet fully solved.

Not long ago a Philadelphia paper quoted a multi-millionaire thus:—"Pittsburg instead of Wall street must be considered hereafter as the potent factor in the continuation of our national prosperity." How typical this is of the present, how significant of the future! The world is recognizing this same fact, that it is the home of the engineer, the country of industry, that must lead the nations in the race for supremacy.

Compare the conditions of fifty years ago with those of to-day. Note the changes the engineer has brought about within our own memory; then who dare say that this advance stops here? Instead I think you will agree with the poet when he says:

"I doubt not through the ages one increasing purpose runs,
And the thoughts of men are broadened with the process of the suns."

If the end is not yet there remains something for us to do, something for us to achieve worthy of our most strenuous efforts.

One writer says: "The great lesson of the nineteenth century was co-operation, the effectiveness of concentration, the efficiency of largeness." Compare the old days of the hand loom in the home, of the shoemaker at his bench, of the individual water power or coal mine, of the small railroad and of the small factory. Compare these with modern methods pregnant as they are with unbounded possibilities, possibilities both of good and evil; of good, for the engineer has provided the means of doing the world's work far more efficiently than ever before; of evil, because the social, the commercial and the industrial systems have not kept pace with the advance made by the engineer, but are yet tainted with injustice and selfishness.

This system of co-operation has made it possible to complete works which otherwise never would have been undertaken. Allow

me to just mention a few of the many engineering feats of the present to illustrate what may be expected of the engineer of the future. See what the railroad engineer is called upon to do because commerce says there must be roads to carry the products and needs of a country. The rapidity with which everything must be done these days demands the shortest and smoothest roads possible, thus requiring the construction of costly bridges and long tunnels. Very striking examples of the latter are seen in the Alps mountains. For ages the Alps had formed a natural barrier alike to conquest or to commerce. In the early part of the nineteenth century, Napoleon, the terror of all Europe, built a roadway across these Alps over which to march his army. The dawn of the twentieth century witnesses a different state. The engineer for the cause of commerce has pierced these mountains in several places and trains steam through almost as swiftly as over the plains of the West.

The St. Gothard tunnel is 9.75 miles long, and next to the Simplon is the longest tunnel in the world. The Mount Cenis is 7.5 miles long, and the Arlberg is 6.25, but all these have to give place to the Simplon, the king of tunnels, which will be 12.3 miles long and pierces the mountain 7,000 feet below the snow-clad road of the first Napoleon.

The dams on the Nile river are other great achievements of modern engineering whch are destined to make the barren land yield food for the human race.

In Western Australia is found another example of what persistent engineers can accomplish. Near Kalgoorlie is one of the richest square miles of territory in the known world, but it being a dry country there was not water at hand to work the mines. Now a supply of 6,000,000 gallons per day is pumped from the Helena river, a distance of 350 miles.

Coming to America we find one of the great projects before the United States is to join the two great oceans by a canal across the isthmus between the continents. Spain was the first to feel the need of this waterway and at one time authorized its construction, but the undertaking was too great for the times. Later French capitalists and others took up the scheme, but thus far no passage for ships exists across the isthmus, and it remains a fitting work for the engineer of the twentieth century.

Hurrying on, let me mention works nearer home. Those at Niagara are well known examples of what coming engineers will be called upon to perform. The small old-time mill would never call upon the mighty Niagara for power, but used the gentle stream, the wind or the horse. The harnessing of Niagara is an accomplishment of these days of modern concentration, where the interests of many are joined in one undertaking, and the needs of the multitude are supplied from one source.

Here, too, is shown how dependent one branch of engineering is on the other. Side by side work all the different engineers, and on the accomplishments of each depends the success of the whole undertaking.

At one time the engineer was looked upon only as a pioneer of civilization, but the present finds him almost as much of a necessity in the centres of population as in the country opening up to the anxious colonists.

Had I time at my disposal I might mention numerous other achievements of like importance and like skill and enterprise, but these will illustrate the fact that the splendor and power of our civilization result from the concentration of forces, both human and material, commanding the resourcefulness of mankind; applying the principles and discoveries of science and developing the resources of nature for this purpose.

What this tendency of concentration requires from the engineer concerns us very much, for it is to meet these requirements that we must prepare ourselves. Such gigantic undertakings require engineers who are specialists in their department, with sound judgment and broad views. The faculty of analyzing what has been done, so as to discover how and why some enterprises have been successful while others are failures, is a natural requisite for the modern engineer. These can not be acquired in a few days, but will take years of careful study and close attention to engineering works. We all must start at the bottom, and they who reach the top must climb. Longfellow's lines are as true of the engineer as of any other:

Heights by great men reached and kept,
Were not attained by sudden flight,
But they while their companions slept
Were toiling upward in the night.

J. F. Hamilton, '03.

MODERN ROADMAKING.

A. W. Campbell, M. Can. Soc. C. E.
Assistant Commissioner of Public Works, Ontario.

For several centuries after the downfall of Rome, roadmaking became a forgotten art. In France, during the eighteenth century, under the engineer Treauguet, road construction was revived, but on very different principles from those followed by the Romans. The type of road built by the French engineer was that introduced into England by Telford, and consisted of a foundation of large stones, laid on edge and carefully shaped, upon which was placed a coating of finer broken stone. Early in the nineteenth century, McAdam advocated and constructed in England a still more economical design in which the foundation of large stone was omitted, but greater care was given to draining the roadbed. McAdam's system is that most commonly followed to-day, with a number of important alterations consequent upon the introduction of roadmaking machinery.

In the time of McAdam the best method attainable was to break stone by hand, which was then placed loose on the roadway and left for traffic to consolidate. The process of consolidation was slow, during which a considerable amount of the stone was forced into and mixed with the earth subsoil, injuring the consistency of the road. Under present methods, by means of a crusher, stone is broken much more cheaply than it could be done by hand.

Stone dust and chips (screenings) are created in the process of crushing, which are used to fill the voids instead of waiting for this to be produced by traffic, or allowing the clay or loam from beneath to be forced up among the stones. With a roller the road metal is made thoroughly compact, forming a strong, waterproof covering over a firm subsoil. The result is that more perfect work is done in a few days and at less cost than the methods of McAdam or Telford would

accomplish in several months. The main features of present day roadmaking, which are of recent introduction, are:

(*a*) The use of grading machines for forming the earth foundation and open drains.

(*b*) The thorough drainage of the earth subsoil.

(*c*) The use of a crusher to prepare the road metal.

(*d*) The screening of broken stone so as to grade it for application to the roads in layers, according to size.

(*e*) The use of stone dust and fine chips (screenings) as a binder.

(*f*) The use of a roller to consolidate both the earth foundation and the surface covering of broken stone.

THE ROAD SURFACE.

A road surface of gravel or broken stone performs various services. The ordinary dirt road of clay or loam alone ruts readily, softens quickly after a rain, and has little supporting power. A well compacted layer of gravel or broken stone over it distributes the concentrated wheel load over a greater area of subsoil; it does not rut readily, and affords good surface drainage. It gives a smooth, hard, wearing surface; water does not easily penetrate it so as to soften and reduce the supporting power of the subsoil.

The depth of gravel or stone to be used must vary with the quality of the material, the amount and nature of traffic on the road and the nature of the subsoil. A dry, compact and stony subsoil needs less metal than does a plastic clay, difficult of drainage. A definite rule cannot be laid down to accurately meet all conditions, but from six to twelve inches of well-consolidated material will afford a sufficient range to accommodate most circumstances. Ordinarily ten inches of metal should accommodate the heaviest traffic to which a gravel or broken stone roadway can be economically subjected.

The amount of crown should not be more than sufficient to provide for surface drainage. A sharp crown tends to confine traffic to the centre of the road; and also in turning out, the weight of the load is thrown on one pair of wheels in such a way as to rut the side of the road. The shape of the crown is a matter on which road experts differ, but with the class of material available for roads in Ontario, and the methods and plans of construction, a form as nearly circular as possible will be found serviceable, and most easily obtained.

From the edge of the open drain the graded portion of the roadway should be crowned with a circular rise of one inch to the foot from side to centre. That is, a driveway of twenty-four feet wide should be one foot higher at the centre than at the side. This amount of crown may at first appear excessive, but with gravel roads and roads metalled with the quality of stones commonly used, is not more than enough to provide for wear and settlement consistent with good surface drainage.

The elevation of the road above the level of the adjacent land need not be greater than is sufficient to provide against the overflow of storm water, which should always be guarded against. The depth of the open drain must vary according to the amount of fall and the quantity of water to be provided for; also according to the sub-drainage needed and provided. When tile sub-drains are used the open drain can often be shallow, in which case the width of the graded roadway can be narrowed, there being no danger of accidents such as are caused by a deep trench at the roadside. The tile drains should be placed below severe frost, and usually a depth of three feet will answer.

ROAD DRAINAGE.

The drainage usually found on existing roads consists of open ditches on each side of the graded portion, with a depth of about eighteen inches. They are frequently carried through rises of ground, past natural watercourses. Little attention is given to the regularity of the grade in the bottom, or to the amount of fall, as evidenced by the varying depths of stagnant water at wet seasons. The object of these drains was more to procure earth to raise the centre of the road above the water line than to lower the water.

The introduction of graders, wheeled scrapers and modern road machinery requires that a roadway should, in order to construct it economically, without hard labor, be such as the implements will readily form. For this reason, deep, open ditches, with sharp angles and narrow bottoms, are not now suitable; but instead, a cross-section of a road should show gentle curves, the rounded surface of the road not sharply defined from ditch. The latter should be about two feet wide in the bottom, where a wheeled scraper can work, and about eighteen inches in depth.

The best practice does not direct that the old open drains should be deepened for the purpose of draining the subsoil. Deep, open drains are expensive, dangerous and unsightly, and the excavated earth generally does more harm than good to the road when used to round it up, especially if piled on top of gravel or stone. When the combined cost of construction and maintenance is considered, a tile drain laid under the bottom of open drains is cheaper and more serviceable.

It may be accepted as a general rule, that roads tiled without gravel are better than roads gravelled without tile. All roads except those on pure sand can be improved by tile draining. A single line of tile, if placed about three feet below the bottom of the open drain, if the graded portion of the road is about twenty-four feet wide, will accomplish nearly all that tile drainage will do. If one side of the road is higher than the other, lay the tile on the high side so as to intercept the subsoil water as it flows down the slope. A four-inch tile meets most conditions, but the size will depend on the length of the drain and the amount of water to be carried away. Care must be taken to give the tile a uniform grade, so that there will be no depressions. If possible, give a fall of at least three inches in one hundred feet. The cost will be about fifty cents a rod. The work, if properly done, will be a permanent and substantial improvement to the road, and will save many times the cost by lessening the amount of gravel needed on the road.

BROKEN STONE.

A great proportion of the macadam roads in Ontario will be constructed of limestone, since this rock is the most common, quarries being within access of almost any part of the Province. In quality it ranges from that which is useless to that which is almost equal to trap. Limestone, if it is tough and close grained, is an excellent material for roads on which the weight of traffic is not excessive. Some dolomitic limestones, while hard, appear to lack in toughness. Other limestones, of a slaty texture, have not good wearing qualities, are rapidly disintegrated on exposure to the atmosphere, and should be avoided. Some limestones of an open, porous nature, yield readily in this climate to the effects of moisture and frost, merely turning into mud. The excellent binding qualities of limestone make up

largely for lack of hardness, a weak cement being formed by the dust, which adds very much to its durability.

All things considered, hardness and toughness to resist wear and atmospheric action, the relative desirability of rocks is ordinarily in the following order: 1, trap; 2, syenite; 3, granite; 4, schist; 5, gneiss; 6, limestone; 7, quartzite; 8, sandstone; 9, slate; 10, mica schist; 11, marble. Of these, the last four, sandstone, slate, mica schist and marble, are of little value in roadmaking except for the lower courses, when they are surfaced with a durable stone that will resist wear.

In determining the best quality of stone for road purposes, there are four prominent destructive agencies which have to be considered: 1, the crushing of loads; 2, the grinding action of the wheels; 3, the blows from the shoes of horses; 4, climatic influences of air, water and frost.

GRAVEL.

Gravel is made up principally of a mass of fragments of stone, rounded and worn, having been transported a considerable distance by water and ice, the pebbles representing the hardest and most durable bits of the rock from which they were detached. With it is commonly mingled a variable quantity of boulders, sand, clay and earthy matter. The rounded, water-worn character of the pebbles composing the gravel does not permit as perfect a bond as is the case with a road covering of crushed stone, in which the sharp angular sides take a firm mechanical clasp.

The test of actual use on the roads is the best means of determining the relative merits of different gravels, but in this case, consideration should be given to length of time each has been in service, the care taken in putting them on the roads, the attention to maintenance and repairs each has received, the nature of the soil on which each is laid, the manner of grading, draining, and preparing the foundation, and the amount of traffic to which each is subjected. The sound made by metal tires in passing over the road is also a means of judging the quality of the gravel. A continuously smooth and grity sound is most favorable; if the grity sound is absent, the gravel contains too much earthy material; while an interrupted, intermittent sound, indicates the presence of large stones. Where sand

and clay are in excess, these should be removed by screening, and the large stones and boulders should be broken. If there is a considerable proportion of the latter, a method which offers many advantages is to place a rock crusher with a rotary screen attachment in the pit, passing all the material through, thereby removing the earthy substances, and breaking the stones with one operation.

THE STONE CRUSHER.

The stone crusher is one of the most important of modern additions to the list of roadmaking machines. By their use stone can be crushed much more cheaply than by the old method of hand breaking. So far as cost is concerned, stone roads are within the reach of every municipality having suitable rock in the vicinity. In the treatment of gravel a crusher is frequently very valuable, since, if containing many large stones and boulders, it will be possible to place a crusher in the pit and pass all the gravel through.

These machines are made after various patterns, the main division into rotary and jaw crushers. Some of the smaller sizes are set on wheels, and may be moved readily from place to place. Others are for stationary work, in a quarry, or at a point to which stone, field boulders, etc., are brought to be broken. They are operated by steam power, a traction engine or stationary engine, or by an electric motor, as circumstances render most advantageous. Some municipalities owning a steam roller obtain power from it, but this is apt to injure the roller.

One of the most valuable features of a crusher is that by attaching it to a rotary screen the crushed stone may be separated into grades according to size, usually such as will pass through a three-inch ring, such as will pass through a one and one-half-inch ring, and fine chips and screenings. By placing the coarse stone in the bottom of the road, and the finest on top, a smoother and more durable road is obtained.

THE ROAD ROLLER.

The advantages to be derived from a road roller in the construction of a broken stone road are becoming more and more appreciated. Unless a roller is used the stone must be spread loosely on the road and left for traffic to consolidate. A road should be made for traffic.

not by it. To leave loose gravel and stone in the roadway is neither an agreeable method of constructing a road nor will it produce the most durable road.

The consolidation of loosely spread stone or gravel by traffic is a slow process, causing much inconvenience to travel, during which the earth of the subsoil becomes mixed with the stone. Earth intermixed with stone prevents the strong mechanical bond which clean metal will assume when the stones are wedged one against the other by a roller. The particles of earth, when wet, have a lubricating influence on the stone, and under the action of wheels the surface is more readily broken up. By the use of a roller the earth subsoil should be first thoroughly consolidated. The stone should be placed on this foundation in layers, and each layer well compacted. In this way a smooth, durable, waterproof coating of stone, free from earthy material, can be laid over a firm foundation.

There are different classes of rollers. The horse roller, weighing six or eight tons, will do fairly well if a steam roller cannot be afforded, but the horse roller is not sufficiently heavy for the best results. It has to be used much longer than the steam roller. The feet of the horses, in exerting sufficient strength to move the roller, sink into and disturb the road metal, and injure the shape and quality of the roadway, while on hills it is at a disadvantage.

The steam rollers are of various weights, ranging from eight to twenty tons. Rollers of fifteen tons weight are those generally used by the towns and cities of Ontario. The cost of horse rollers is usually about $90 per ton, or from $400 to $600 each. Horse rollers are, however, generally so constructed that the weight may be increased by iron castings, so that a roller of five tons may be made to weigh about six. Steam rollers cost about $3,000. For operation a horse roller, with two teams, will cost $6 per day. A steam roller will cost $10 a day, including interest and depreciation, but will do several times the amount of work done by a horse roller, so that the saving in operation is considerable.

The amount of rolling which can be done in a day varies according to the quality of metal used, the kind and amount of binder, the thickness of the layer of stone rolled, and the weight and type of roller. With broken limestone, rolled by a twelve ton steam roller,

the amount of stone compacted will average between forty and fifty cubic yards in a day of ten hours.

ARCH CULVERTS.

Concrete or other durable tile are to be recommended for small waterways, where there can be no doubt as to their sufficiency to accommodate the maximum flow of water. A difficulty with tile, however, has been that they are frequently used in places where a larger waterway should be provided; and while they may be large enough for the greatest flow of water for a period of years, yet there is apt to come a time of sudden flood or freshet when they are subjected to a rush of water for which they have not capacity, and a washout results.

For this reason, when putting in culverts which it is desired shall be permanent, care should be taken to provide a waterway of ample size for the unusual, not the usual, amount of flow. To this end arch culverts of concrete or stone masonry should be employed. Of the two materials, the cheaper is concrete made of gravel and Portland cement, or of broken stone, sand and Portland cement. If properly made, concrete is not only cheaper but is equally as durable as stone masonry.

The cost of a concrete culvert will range from about $4.50 to $6.50 per cubic yard of concrete in the structure. This variation is created by various details—the availability of gravel, the cost of Portland cement, the cost of labor and other items. The first to be constructed by a municipality always costs more than subsequent work.

A stone arch is so designed that the stones will remain in place without being held together by mortar. Concrete arches, on the other hand, are dependent upon the cohesive strength of the materials. Good workmanship and good materials are, therefore, of exceedingly great importance in building concrete arch culverts. It is also essential that the side walls of arch culverts shall rest on a firm stratum of hard-pan, gravel, compact earth, or other unyielding base, so that there will be the least possible settlement. If settlement occurs to any extent, it is rarely uniform, and the arch is thereby distorted and cracked. Usually it is necessary to excavate, for the side walls, a depth of about three feet below the bed of the stream. A certain

depth is necessary in any location in order that the side walls may not only be safe from settlement, but also from the undermining tendency of the stream.

TILE CULVERTS.

The manufacture of concrete tile for culverts is a very simple matter, and can be undertaken by the municipalities themselves, although in numerous cases they are now manufactured as a private enterprise. Just such a number of pipe as are actually required for the season's work need be manufactured; the implements required are inexpensive, and the pipe may be made by the municipality for actual cost, which, after a little experience, can be reduced to a very small amount.

The implements required are of the simplest kind. The most important are two steel spring-cylinders, one to sit inside the other, leaving a space between the two equal to the thickness of the finished concrete pipe. These can be procured from the manufacturers of road-making machinery. By "spring-cylinder," it may be explained, is meant such a cylinder as would be formed by rolling a steel plate into a tube without sealing the joint. With the smaller of these cylinders the edges overlap slightly, but are so manufactured that the edges may be forced back and set into a perfect cylinder. With the larger, the edges do not quite meet, but may be forced together and fastened. Accompanying these moulds are bottom and top rings which shape the bell and spigot ends of the pipe.

The two cylinders, with joints flush, are set on end, the one centrally inside the other, and on the bottom "ring," which in turn rests on a firm board bottom. The concrete, made of first-class cement and clean screened gravel in the proportion of one of cement to three of gravel, is then tamped firmly into the space or mould between the two cylinders. The tamping-iron used to press the concrete into place is so shaped as to fit closely to the cylinder.

The concrete is allowed to stand in the mould for a short time, when the cylinders are removed; the outer and larger cylinder by removing the clamps, and allowing the edges to spring apart; the inner cylinder by removing the fastenings, so as to allow the edges to again overlap, returning to the shape of a coil. The outer cylinder having thus been made larger and the inner one smaller, they can

be readily taken away, and the concrete pipe is then left until thoroughly hardened. For the larger sizes, the two halves of the outer cylinder are usually hinged, and can be more carefully removed than when allowed to "spring" from the concrete.

The concrete adheres closely to the metal, and to overcome this it is necessary to keep the moulds well oiled. This should be done after each tile is made, and, when the moulds are by this means kept perfectly clean, a smooth and uniform pipe of good appearance will be obtained. A good mixture for oiling the moulds is composed of two parts of machine oil to one part of coal oil.

BRIDGE FLOORS.

Among the recent uses to which concrete has been applied is the making of bridge floors. In the county of Elgin more of this class of work has been done than elsewhere in the Province, and so satisfactory has experience been with these floors that they are being used on all county bridges. Plank floors wear out in from two to four years, and are a constant matter of expense.

Concrete adds a considerable load to the dead weight of the bridge, but this is more than compensated for by the extent to which it distributes the live load. With a plank floor the weight of every vehicle passing over is transmitted to the individual members of the bridge, causing a constant jarring and distortion that is very destructive to steel. With concrete, on the other hand, the weight of a passing vehicle is spread over a much greater area of the bridge structure, the floor being a monolith and distributing the live load over a much greater bearing than can each plank. In this way the injury to bridges is much less with a concrete than with a plank floor.

So much is this the case that, with a concrete floor, it is not necessary to restrict the speed of vehicles travelling over it. With a plank floor it is always expected that horses will not be driven over the bridge at a faster rate than a walk. But with concrete floors travel is not interfered with, and horses may be driven over at the ordinary pace.

ROAD LOCATION AND PERMISSIBLE GRADES.

E. A. James, '04.

The question of good roads is not a new one to members of our Society; several phases of the subject have been discussed. Roadway engineering is however becoming more and more important and I therefore make no apology for calling your attention to road location and permissible grades.

A good road is a public benefaction. Every member of the community receives pleasure and profit from it. It is a distributer of good things, a lightning rod to attract intelligent residents to a community. They are the basis of our transportation system—without good roads any community is handicapped in its race to the world's markets.

It is strange that although during the last two or three decades great strides have been made in railway and steamboat transportation routes, little if anything has been done to improve our waggon road system.

The ideal good road ought to be smooth; it ought to give good foothold for the horses; it ought to be impervious to water; it ought to be durable and have a good wearing surface; it ought to have a good foundation and be easily drained, and the steepest grade on the road should be that at which the vehicle would just be on the point of rolling down if left to itself. Very few, if any, of our roads come up to this ideal.

Location.

The location of a road is one of the fine arts of the engineering profession, learned not in the college halls, but in the school of experience. The proper location of a road is of greater importance than

its construction. Not that good location and poor construction will give a good road, but rather that mistakes of construction may be corrected year by year; but the mistakes of location, because of land damage claims, the trouble and expense of re-arranging road and buildings, and the dread councillors have of losing a vote or two, for these reasons mistakes of location are never, or at least, seldom corrected. A whole neighborhood may grumble daily at having to use a certain piece of road, but try to re-locate that road through one man's farm and in a few hours he will create a greater disturbance than you thought possible.

Many of our roads were originally located without any attention being paid to the general topography of the district. They followed the immigrant's trail or the road allowance of the original survey regardless of suitability, either as to situation or grades.

Just now in Western Canada they are following in many cases the section lines. If the line of travel should happen, as it often does, to be cornerways across the sections, you have to follow a rectangular zigzag. This often necessitates crossing and re-crossing railways, streams, and steep hills. A properly located road would avoid this.

Graceful and natural curves conforming to the lay of the land add beauty to the landscape, increase the value of property, as well as give an easier and better road.

In considering the location of a road, width should be considered. In Canada we appear to have two standard widths, 66 feet and 99 feet. Since the cost of maintaining a road is not in proportion to its width, but more in proportion to the traffic passing over it, why not always take the wider road when you can get it? If the road is not well formed it allows of several tracks, far more room to pass soft spots and greater convenience in travel. If the road is well formed it allows avenues of trees at sufficient distance from the road bed so that they do the minimum amount of damage. Trees too near a roadway not only deprive the road of the action of the air and sun, but they further injure it by the dropping of rain from the leaves, and as a consequence the road is left wet long after it would otherwise be dry.

In locating a roadway a firm, dry road is desirable. If this cannot be secured, then a road that can be easily surface drained, and as easily underdrained.

Side hills give a better road than river bottoms. They are always better drained, and generally have a more solid foundation. If located on side hills facing south and east the road will dry more quickly, and will be more solid than if on hills facing north and west.

Snow is an obstacle encountered in road making, in the open country as drifts, in the mountain districts as drifts and snow slides. The track of the snow slides is usually well marked, sometimes the vegetation marks well where the large snowbanks lie. If you are in doubt call in the neighbors, they will give you plenty of suggestions; they may be prejudiced, but by careful watching you will be able to get the information desired. From the direction of the prevailing winds and the slope of the hills you can also judge fairly well where the snow will lodge. Deep ravines always are well supplied. Sometimes you can avoid snow by crossing to the other side of the ravine, or you may be able to go around the hill by a side hill grade, without cutting into the face of the hill. In that case the snow might slide over your road and stop below it. The accumulation is at times so great and the cost of removing it in the cold, short days of winter is so excessive that it is usually allowed to remain for the sun and wind to remove. It is wisest economy to avoid snow slides at almost any cost.

Although the ideal road would be the air line, if level, yet a road should never go over a hill if it might go round it. The labor and expense put upon it are absolutely wasted. The difference in length between a perfectly straight road and one which is slightly curved is not so great as one would at first imagine. Sganzen says:—"If a road between two places, 10 miles apart, were made to curve so that the eye could see no farther than one quarter of a mile of it at once, its length would exceed that of a perfectly straight road between the two points by only about 150 yards."

Frequently the distance around a hill is no greater than the distance over it.

In laying out a road straightness should always be sacrificed to obtain comparatively level surfaces, even if the horizontal distance has to be increased. In general, to avoid steep grades, it is considered good engineering to lengthen the road, favoring economy in construction, reduction in traction effort, increase in speed, and economy in repair.

This now brings us to the most important principle in road construction, namely, grades.

Grades.

The resistance on grades is due to the force of gravity, and is theoretically the same on good as on bad roads. Gillespie gives the following results, that are of great importance in this matter. A horse that can draw on the level 1000 pounds can draw on a 1 per cent. grade, 900 pounds; 2 per cent. grade, 810 pounds; 2.5 per cent. grade, 750 pounds; 3.3 per cent. grade, 640 pounds; 4.0 per cent. grade, 540 pounds; 5.0 per cent. grade, 400 pounds; 10.0 per cent. grade, 250 pounds.

The United States Department of Agriculture in a publication called "Traction Tests," gives a table of great practical value. Part of the table is given here. Instead of giving the load that can be pulled, they give the tractive force necessary to draw one ton over the best macadam road, of various grades, and the equivalent length of each mile of grade in miles of level road.

Grade.	Angle with level	Tractive force.	Equal length of level road in miles.
Level	0° 00′ 00″	38 pounds	1.00
1 per cent.	6′ 53″	42 "	1.10
2 "	1° 08′ 16″	78 "	2.05
2.5 "	1° 25′ 57″	88 "	2.30
3.3 "	1° 54′ 37″	104 "	2.73
4.0 "	2° 17′ 26″	118 "	3.10
5.0 "	2° 51′ 21″	138 "	3.63
10.0 "	5° 42′ 58″	238 "	6.26

If with these two tables you have, in addition, that of Rudolp Herring, published some years ago in the Engineering Record, one is in a position to calculate approximately what is the permissible grade. Herring's table is (in part) as follows:

When the rate of travel is 3 miles per hour on a

Loose sand road, with a load of 1 ton, traction force required is					448	lbs.
Loose gravel (4 in.)	"	"	"	"	222	"
Common gravel	"	"	"	"	147	"
Good gravel	"	"	"	"	88	"
Hard rolled gravel	"	"	"	"	75	"
Ordinary dirt	"	"	"	"	224	"
Hard clay	"	"	"	"	112	"
Hard dry dirt	"	"	"	"	89	"
Macadam, little used	"	"	"		140 to 97	"
Bad macadam	"	"	"	"	160	"
Best macadam "	"	"	"		32 to 50	"
Asphalt	"	"	"	"	17	"
Iron railway	"	"	"	"	11½	"

Here then we have the tractive force exerted on roads constructed of different material, and the relative tractive force required for different grades.

The next question is what may be the limiting grade or the greatest allowable grade on any road.

Before taking up the question of limiting grades, it might be well to consider the question of foothold of horses. Relatively speaking, when grades are steep a horse can haul more on a dirt road than on an asphalt or broken stone road. Descending a hill a horse can also hold back more. At certain seasons of the year even dirt roads become so hard and compact that it is impossible for a horse to secure good foothold. The only safe grade is a low one. In other words, the smoother the road the less the grade should be.

Limiting Grade.

From these tables it will be observed that a horse can not draw three-fourths as much on a 2.5 per cent. grade as on the level. On

a 5 per cent. grade he cannot draw half as much as on the level, and on a 10 per cent. grade only one-fourth as much as on the level. The difficulty as well as the cost of hauling is therefore necessarily increased in proportion to the steepness of the grade.

The proper grade in any case must be determined by conditions and requirements.

If for bicycle travel, a 2 per cent. grade can be ascended with comparative ease, and descended with little effort. A 4 per cent. grade is practicable when unavoidable. The average bicycle rider can ascend without much trouble and descend with comparative safety. Grades above 5 per cent. are too steep for comfort either in ascent or descent.

For carriage driveways the grade should not exceed 4 per cent. A good horse with a light buggy and two persons will trot easily up such a grade, and as easily down without a brake. On a steeper grade the strain becomes too apparent for comfort.

For freight roads the English engineers appear to favor 3 per cent. as the ruling gradient.

American engineers, outside of the Mountain Districts, try to keep their grades below 5 per cent. Of course in this they sadly fail but that appears to be their ideal grade.

On a road with grade no higher than 5 per cent. two horses averaging 1,300 pounds each, could freight, at the rate of 3 to 3.5 miles per hour, two tons; or if you wish more details, the average horse used in freighting can draw up a 5 per cent. grade, on a macadam road, 1,840 pounds; on an earth road, 1,500 pounds; 780 on a muddy road, and about 600 on a sand road; while on a 10 per cent. grade the numbers would be 1,060, 930, 600 and 300.

For freight traffic the maximum grade admissible is 10 per cent. Experience shows that waggons can be satisfactorily controlled in all weather on such grades. When the grades are steeper than this accidents are of frequent occurrence. Even rough locks are not able to control the waggon in descent. On a properly constructed, dry road, four animals, averaging 1,300 pounds in weight each, will haul

6,500 pounds total weight, distributed between waggons and contents, over a 10 per cent. grade at the rate of 1.5 miles per hour. On long hills it is best, when possible, to make breaks in the grade—that is to have short level stretches or landings, so as to relieve the strain on the team. If the hill is of such a character that you can have two or three grades of different steepness then I would suggest that you have your steepest grades at the bottom. For a short time a horse can more than double his tractive force, and is best able for this effort when coming in off a comparatively level road. In descending it does not matter so much if the teamster does develop at little speed on the last grade.

STEAM TURBINE TESTING AT THE WESTINGHOUSE MACHINE COMPANY.

A. G. Christie, '01.

Mr. George Westinghouse says, "We need not call the steam turbine the engine of the future, it is decidedly the engine of the present." Hence all engineers of the present day and those of the future as well, should become thoroughly acquainted with the characteristics of this type of engine, such as construction, test and operation. The mechanical construction and the practical operation of the Westinghouse Steam Turbines have already been described many times in the technical press and elsewhere. I assume these descriptions have been quite generally read, and so shall not discuss these subjects in this paper. However, I believe that the following description of the testing plant, and methods of test for steam turbines at the Westinghouse Machine Company, will be interesting to engineers and instructive to students of engineering.

The works of the Westinghouse Machine Company are located in the Turtle Creek Valley at East Pittsburg, about 12 miles from Pittsburg, and on the main line of the Pennsylvania Railroad. The main shop is about 1,400 feet long and 300 feet wide, and consists of two main aisles and two side bays, and a center bay, above which are galleries. The offices of the Company occupy one portion of this building. All machine work is done in it.

All gas, steam and Corliss engines are erected and tested in it as well. Parallel to the main building is another one, about 1,200 feet long and 60 feet wide, containing store house, forge shop, power house and steam turbine department, in the order named. The steam turbine department occupies about 500 feet in one end of this building.

Beside this building on the farther side from main shop are laid the double tracks of the Westinghouse Inter-Works Railroad, which road connects the various Westinghouse Works in the Turtle Creek Valley, and in all is about seven miles long. Beyond the tracks and parallel to them flows a fair sized stream known as Turtle Creek. The Pennsylvania Railroad tracks are on the other side of this stream.

The Steam Turbine Department is devoted wholly to the building and testing of steam turbines. Fig. 1 shows a view down the

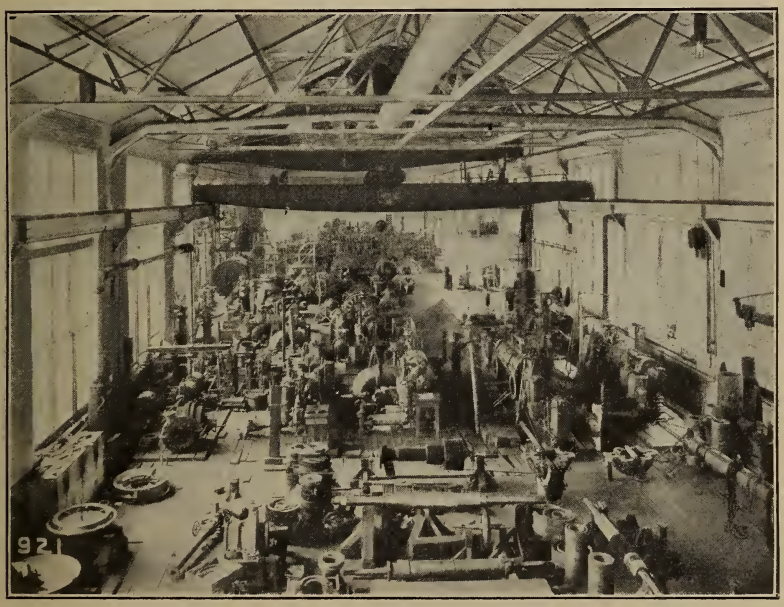


FIG. 1—VIEW OF STEAM TURBINE SHOP FROM WASH ROOM GALLERY.

shop from the wash room gallery. The parts after being machined are brought from the main shop by a system of industrial railways, the cylinders and spindles are bladed and the whole engine assembled. Fig. 2 shows a view of a number of 400 K. W. engines already assembled and ready to be taken to the testing floor as their turn comes. This shows plainly that the Westinghouse Steam Turbine has passed from an experimental into a commercial stage of development, as all the engines shown in the view are already sold. A space

of about 200 feet in the central part of this department has been built and equipped especially for testing. This testing plant is undoubtedly the finest of its kind in the world. A visitor is at once impressed with the permanence of all construction work, the completeness and superiority of the equipment and the practical and scientific manner in which tests are conducted. In fact, tests are made daily with as much care and accuracy as in the best equipped college laboratory. Another very valuable feature to the purchaser is the fact that he can have his engine tested before leaving the shop under identically the same conditions he may wish to operate it at, and obtain definite results, as steam consumption, etc., instead of results calculated from diagrams.

A plan of the testing department is shown in Fig. 3. From this it will be seen that there are two separate and independent sets of testing floors A. and B., each with its own system of piping, circulating pump, condenser, hot well pump and weighing tanks. As yet only one air pump of large capacity has been installed, though another is about to be.

The larger of these test floors, A., Fig. 3, has four stone foundations 50 feet long and 5½ feet wide, capped with cast iron surface plates. The pit between these is 6½ feet wide and 8½ feet deep. A tunnel 7 feet wide and as deep as the pits runs along one end for a passageway, and to hold the live steam pipes. This floor is for testing engines of 750 K. W. size, and larger. The engine bedplate being of box pattern, bridges one of these pits. Fig. 4 shows a 1,250 K. W. turbine on the test floor. The exhaust pipe lines are placed in these pits, being connected through the bedplate to the exhaust end of the turbine. The exhaust lines are 36″ diameter, and connect with a main header in the cellar. This header passes along the ends of the pits and enters the bottom of the condenser by a T pipe. The hot well of the condenser is attached to the lower arm of the T. pipe. This arrangement allows steam already condensed in the exhaust line, to pass into the hot well without having to enter the condenser. The exhaust line is provided with an atmospheric exhaust relief valve C, Fig. 3, and also with suitable means for completely shutting off any

branch leading up the pits. Thus any one engine can be operated and tested with all other engines on the floor shut off from the main exhaust line.

The condenser, marked D, Fig. 3, is of the surface type built by the Alberger Condenser Company. It sits on the shop floor as shown in the photograph, Fig. 5. The shell is of riveted steel. The tubes are of thin brass and present 8,000 sq. ft. of cooling surface. Its capacity is 3,000 H. P. The steam enters from below as just ex-

FIG. 2.—SOME 400 K. W. STEAM TURBINES ON ASSEMBLY FLOOR.

plained. The pipe to the air pump is connected at the top. A separator is placed at the highest point of this pipe to drain back any partly condensed steam that may be drawn over.

The air pump is of the two-stage, tandem, dry vacuum type, also built by the Alberger Condenser Company. A photograph is shown in Fig. 5. Its two air cylinders are 18″ diameter, and are fitted with mechanically operated slide valves. The steam cylinder is

8″ x 24″, fitted with Corliss valve gear. The pump sits on a masonry foundation and on the level of the shop floor in a position marked E in plan, Fig. 3.

The circulating water is supplied by a 16″ centrifugal pump, built by the Kingsford Foundry Company, making 350 R.P.M. and capable of delivering 6,500 gals. per minute. A photograph is shown in Fig. 6. It is directly connected to a 9½ x 9″ Westinghouse Standard Engine. These are placed in the cellar at F, Fig. 3. The circulating water is drawn from an open sump in the center of the cellar at G, Fig. 3. This sump is 60 ft. long x 18 ft. wide x 20 ft. deep. Outside, Turtle Creek has been dammed, and an effective screen has been built before the mouth of a tunnel from which, by gates, the water is allowed to flow into the sump inside, thus assuring a continuous supply of water, even in dry seasons. After passing through the condenser, the water is discharged into the creek below the dam. The outlet of the discharge pipe is kept submerged, thus saving priming the centrifugal pump every time it is started.

The condensed steam in the condenser drains into the hot well from which it is pumped by a 7½ x 7½ x 6″ Alberger duplex pump, placed directly under the hot well. It is discharged through a pipe which carries it to the weighing tanks at H, Fig. 3. By means of a three-way cock, it can be made to discharge into either one of these as required. The weighing tanks, each of 500 gal. capacity, are mounted on scales on a suitable platform, as shown in the photograph, Fig. 7.

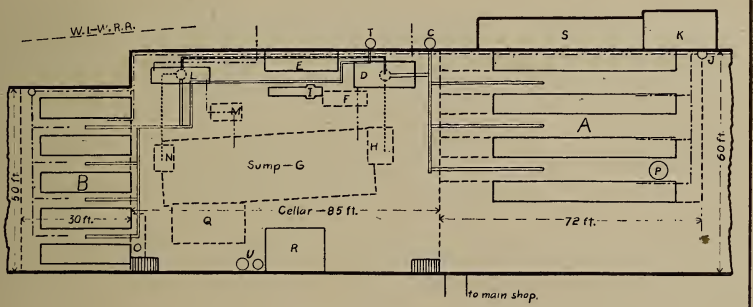
Exciting current for the fields of alternating current generators on the test floors, is supplied by a 120 K. W. turbo outfit on the shop floor at I, Fig. 3. A photograph is also shown in Fig. 5. This outfit consists of a 120 K. W. steam turbine with a direct current generator running at 3,600 R.P.M. It produces an even and steady supply of current.

Steam comes from the boiler house, through a 12″ pipe to the separator at J, Fig. 3, which removes any condensation. After the separator is a system of valves by which the steam can be passed through the superheater or sent direct to the test floors. The superheater is placed in an addition to the shop as shown at K, Fig. 3.

It is similar in construction to a Babcock & Wilcox water tube boiler, has steel tubes, and contains 800 sq. ft. of heating surface. It is independently fired, natural gas being the fuel. Successful tests have been run when the temperature at the superheater outlet was 650° F., which at 150 lbs. boiler pressure, meant a superheat of nearly 300° F.

In the boiler house are four batteries of Babcock & Wilcox water tube boilers of 500 H. P. each, which, with the vertical boilers located

Fig. 3.



PLAN OF STEAM TURBINE TESTING DEPARTMENT

Westinghouse Machine Co.
East Pittsburg, Pa.

Live Steam Pipes,
Exhaust Pipes,
Circulating Water Pipes
Hot Well Discharge Pipes,
Air Pipes from Condenser

A.F.Christie

over the forge shop heating furnaces, give a total capacity of 3,000 boiler H. P. The safety valves are set at 160 lbs., which of course, imposes this limit upon the steam pressure for testing purposes. In fact, this is the only limit to the capacity of the plant for regular test work.

The steam for all the pumps connected with the testing plant and also the exciter turbine, is always taken from the separator just described, so that it is not superheated. These engines are not built to stand superheat, and all run non-condensing.

The other test floor B, Fig. 3, in general arrangement, is a duplicate of the one already described, but for all engines of smaller size than 750 K. W. It has five foundations 25 ft. long and 5½ ft. wide, of similar construction to those already described for the other floor. The pits however, are much shallower, being only 5 ft. 6 in. deep and 4 ft. 6 in. wide. As, on the other floor, the exhaust pipes which are 20 in. in diameter, are laid in these pits. These connect in the cellar to a main header 24 in. in diameter, which passes along the ends of the foundation, and enters the bottom of the condenser by a T pipe, with the hot well attached to the lower branch, as at the other condenser. As on the other floor, all engines except the one to be tested, can be blanked off from this main exhaust header. As the present type of 400 K. W. steam turbine as shown in Fig. 8, has a very narrow bedplate, and exhausts from one side, it is placed on the foundation instead of bridging the pit, and is connected to the exhaust line by an elbow.

In the view shown in Fig. 1, the test floor now under discussion, is shown in the foreground, with a number of engines in various stages of testing. The exhaust line is also provided with an atmospheric relief valve, shown at T, Fig. 3.

Steam for this floor is brought from the valves at the superheater, through a 6 in. pipe to the farther end of the floor. This pipe is carried along the wall and is heavily lagged throughout its length, in all, about 220 ft. At the test floor it turns down under the floor and passes along a tunnel at the end of the foundations, from which connections are made for each individual engine. A separator, placed on the main line, just as it passes below the floor, removes all condensation.

The condenser, L, Fig. 3, is of the surface type, with a cast iron body, built by the Alberger Condenser Company. It contains 3,000 sq. ft. of cooling surface, and has a capacity of 1,000 H. P. Steam enters from below as just described. The air pump already described, serves this condenser also, and is piped up in a similar way with a separator on the air line. This pump has sufficient capacity to maintain a 28 in. vacuum on both condensers, with an engine on each floor.

The circulating water is supplied by a 14″ x 20″ x 18″ duplex pump, placed in the cellar at M, Fig. 3, built by the Stilwell-Bierce & Smith-Vaile Company. The water is pumped from the sump and discharged into the creek outside. The condensed water is pumped from the hot well by a 6″ x 5¾″ x 6″ duplex Alberger pump placed below the hot well, into a similar but smaller set of weighing tanks to those previously described. These are placed at N, Fig. 3, in the cellar, and are of 360 gallons capacity each. After weighing, all the sets of tanks discharge their contents into the sump.

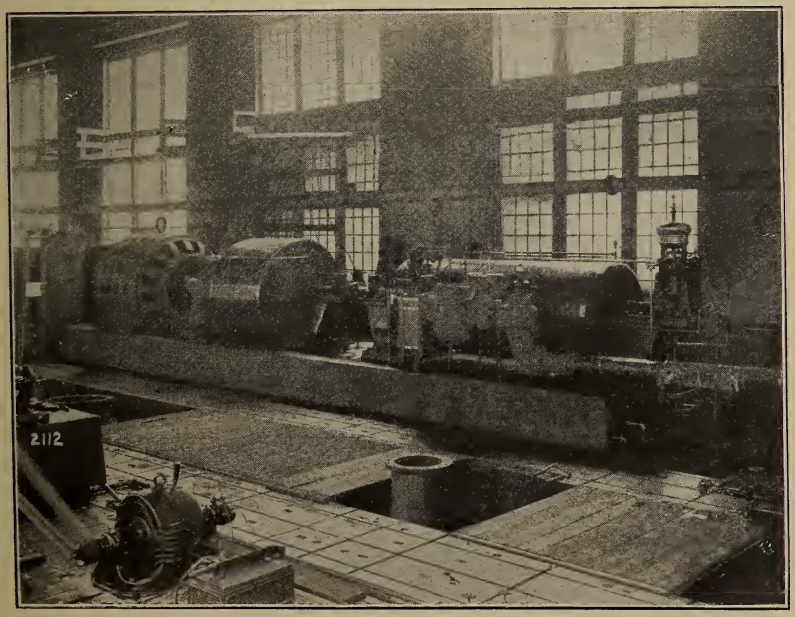


Fig. 4.—1,250 K. W. Steam Turbine on Test Floor.

At Q, Fig. 3, a complete testing outfit for experimental work is located. On the shop floor an iron bedplate has been placed. In the cellar, directly below this, is a surface condenser, with 1,600 sq. ft. of cooling surface. The exhaust enters from above, a hole being cut through the floor for the exhaust pipe. Below is the hot well. A vacuum pump, which serves both as air pump and hot well pump,

discharges the condensed steam into weighing tanks mounted on scales, as in the other sets. A duplex pump 8″ x 12″ x 12″ supplies circulating water from the sump, discharging into Turtle Creek.

It may be interesting to note that with any one of these condensing outfits, tests can be, and have been made with the engine running non-condensing, and without back pressure, and yet condensing all the steam used and weighing it. A simple arrangement allows the air to escape from the condenser, but no steam can pass out.

A large oil tank and an oil filter have been placed on the shop floor at U, Fig. 3. In the cellar, a small duplex pump and a system of supply and return oil pipes from these tanks, to both test floors, are installed. Connections are made from these pipes to the engines on the test floors so that oil can be pumped into an engine from the supply tank or from the engine into the filter.

All the pits and the cellar are concrete floored and lighted by incandescent lamps. The shop floor above the cellar is of iron plates supported on steel beams.

All shifting and placing machines on the larger test floor is done by either of two 20 ton electric cranes, which traverse the whole length of the shop, up to the smaller test floors. These floors and the remainder of the shop, are served by a 10 ton electric crane.

On the shop floor at R, Fig. 3, are the foremen's offices, and calculating room, where any office work in connection with the tests can be done.

Probably before going farther, it may be well to describe some of the features of the steam turbine, especially the newer ones. Westinghouse Steam Turbines have been built in two types, single cylinder and two cylinder. The two cylinder type, of which the 750 K. W. shown in Fig. 9, is a sample, consists of a high pressure cylinder, in which the steam is expanded from inlet pressure down to about atmospheric pressure, and a low pressure cylinder, where the exhaust from the high pressure cylinder is expanded down to vacuum pressure. These cylinders are connected by a receiver pipe under the bedplate. The bedplate is of ribbed box type, sufficiently strong and rigid to support the engine and generator when bridging the pit. These

two cylinder engines have been built in sizes from 750 K. W. to 1,500 K. W. The single cylinder engines have been built in sizes from 400 K. W. to 1,500 K. W. At present, single cylinder engines of 5,500 K. W. are under construction. A photograph of a 5,500 K. W. is shown in Fig. 10.

The dimensions may be interesting:

Extreme length, including generator.....47′ 3″
Extreme width, including generator.....16′ 0″
Height above floor .....14′ 0″

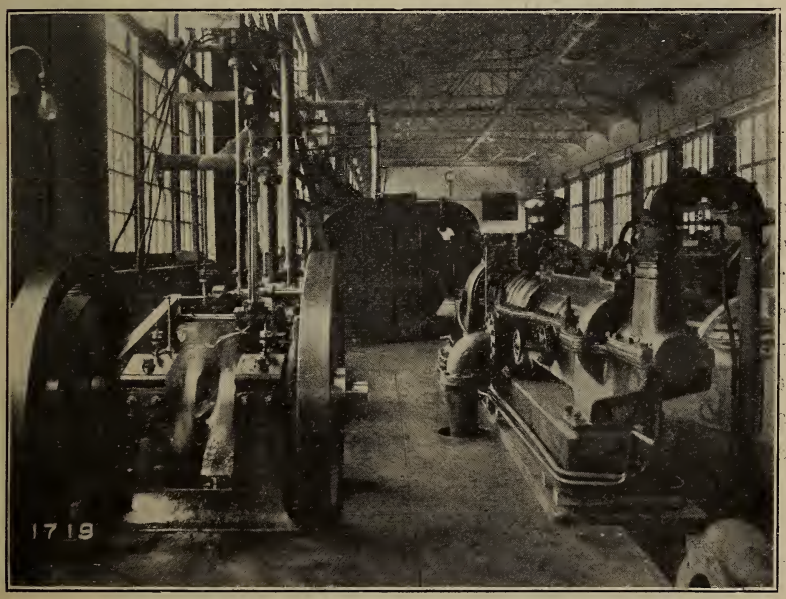


Fig. 5.—Air Pump, Exciter Turbo and Large Condenser.

Maximum overload capacity will be about 1,300 h.p. On this basis we have 17 h.p. to the sq. ft. including generator.

Fig. 11, shows a section of a 400 K. W. steam turbine. The revolving spindle is shown with bearings at J and J, with an aligning bearing at H. It is coupled to the brake or generator shaft by a

solid sleeve coupling R, on the outer face of which is cut a worm which engages a worm wheel on the shaft which drives the oil pump M, and also serves to oscillate the governor motion, the centrifugal element being driven by bevel gears from the shaft. Steam enters from the poppet valve at A and passes through the blades into the exhaust B. A by-pass is shown at P. C, C_1 and C_2 are the balance pistons. A portion of the bedplate, in section, is shown containing the oil cooling coil T. Cold water is circulated through this chamber to cool the oil. The governor is shown at O.

A feature which has proved very successful is the automatic quick-closing, throttle valve. This is placed on the main steam line so that the entering steam has to pass through it before entering the hand operated throttle valve. On the extreme end of the spindle shaft, a small centrifugal governor is attached so designed as to release a small plunger when the speed of the turbine reaches a certain percentage above normal speed. This plunger on release, opens a port and allows the steam to exhaust from under an overbalanced differential piston on the automatic throttle valve stem, and causes this valve to close instantly. Hence, when in operation, should the speed of the turbine for any reason whatever, exceed the pre-determined limit of the small governor, it releases the plunger, the automatic valve shuts, steam is entirely cut off and the engine automatically shuts down. The engine shown in Fig. 4, is fitted with this automatic throttle valve.

Another feature is the automatic secondary valve. This consists of a double beat poppet valve, relay cylinder plunger, etc., as in the main valve, and is similarly actuated by the governor. Should the turbine become overloaded beyond a certain capacity, the governor starts to operate this automatic secondary valve and allows steam at boiler pressure to enter the second stage of blades. Fig. 10 shows this valve on the 5,500 K. W. engine.

Whenever possible, brake tests are made on the steam turbines, thereby avoiding the trouble and expense of an electric test. A water brake, which has proved the best after a number of experiments on the test floors with various types, is used for these tests. The water

brake has been especially developed for turbine testing work, and has proved to give highly gratifying results, not only from the standpoint of constancy and accuracy of loading, but from ease of manipulation and freedom from excessive attention.

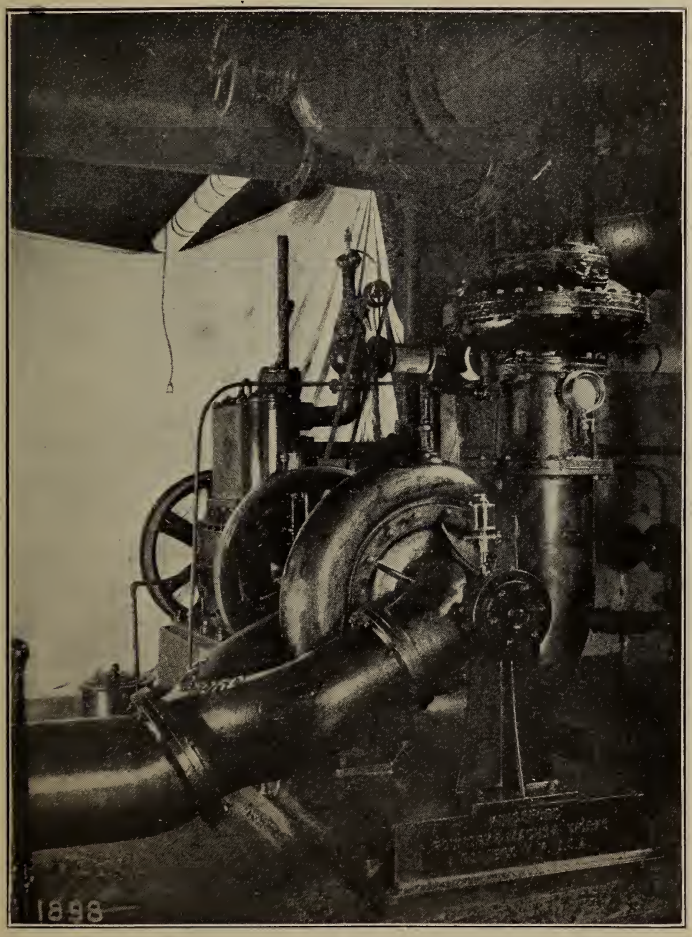


FIG. 6.—CIRCULATING PUMP FOR LARGE CONDENSER.

These brakes are very powerful. One small brake used for testing 400 K. W. engines, running at 3,600 R.P.M., has carried 1,100 brake horse power, and others have been used up to 2,500

h.p. The load can be changed almost instantly by simply regulating the water supply by a small hand valve. Water is supplied for use on the brakes from a system of water pipes placed in the pits. The oiling of the brake bearings is done by the turbine oil pump, as for the other bearings of the engine, and hence is automatic after the engine is up to speed.

To show the speed of the turbine at any instant, a tachometer of standard centrifugal type for high speeds, is belted to the turbine or generator shaft at some suitable point. Quite close readings can be made on it. A Veeder tachometer using alcohol, is also included in the test floor equipment, and gives even more accurate readings than the centrifugal tachometer. When an engine is carrying a given load for a certain interval of time and the speed (constant so long as the load is constant) is to be accurately taken during that interval, a continuous counter is attached to some part of the governor case, so as to register the number of strokes the oil pump makes. As already shown in Fig. 11, the oil pump is directly driven by a worm and worm wheel, and eccentric, from the turbine spindle. The ratio of the worm and the worm wheel is known. The speed of the turbine spindle can be found by multiplying the register of strokes of the oil pump, as shown by the continuous counter by this ratio. Oil pumps make from 150 to 175 strokes a minute according to the size and speed of the engine.

For tests not using superheat, a throttling calorimeter is used to determine the quality of the steam. The standard size used on the test floors is that found by experiment to give most accurate results. These are carefully lagged and can have their exhaust so regulated as to give in all tests the same absolute back pressure in the calorimeter, as shown by an attached mercury column. This absolute back pressure is 18 pounds. These calorimeters give very accurate results, being checked by a thermometer placed in the steam line beside the calorimeter, which indicates the temperature of the steam the moment it arrives.

On account of the distance from the boilers, the superheater is used when dry saturated steam tests are to be made, enough heat

being supplied to give dry steam at the calorimeter. Each individual test floor is supplied with a calorimeter permanently attached to the steam supply line.

When tests with superheat are made, a thermometer, placed in a mercury cup fitted in the top of the steam strainer, gives the temperature of the steam as it arrives at the throttle. All thermometers are high grade, made by reliable concerns. They are the usual glass mercury bulb style and read up to 500° F. and 700° F.

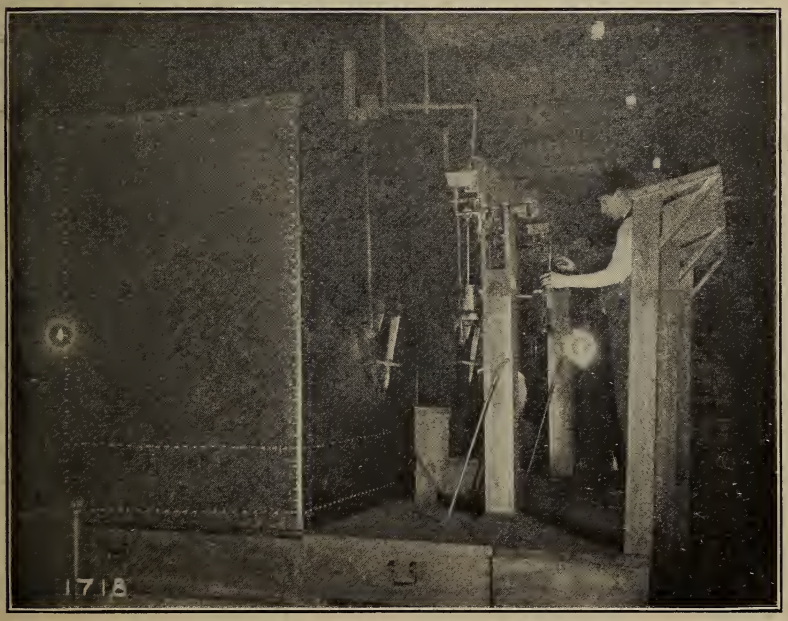


FIG. 7.—WEIGHING TANKS AND PLATFORM.

The gauges used are made by well-known firms, and are carefully tested both before and after tests. Usually, only two sizes are used, *i.e.*, those reading to 160 lbs. and compound gauges reading to 30 lbs. pressure and 30 in. vacuum.

The vacuum is measured by a mercury column with carefully graduated and plainly marked seals. This is mounted in a suitable case, and on a firm stand. It can thus be moved around the shop

without fear of breakage, and can be connected to any exhaust by ¼ in. pipes provided for this purpose. The testing department is provided with two of these movable columns. Several other mercury columns are also provided; also U tubes for mercury to use at calorimeter and in experimental work.

The vacuum can be regulated to almost any desired degree. The exhaust lines have been so well connected up that vacuum of 29⅜ in. has been carried at the exhaust of an engine with a barometer of only 29¾ in. Lower vacuums are obtained by reducing the supply of circulating water for the condenser until the mercury stands about ½ in. above the required height. It is then regulated by allowing air to leak through an adjustable opening, into the exhaust line. On the small condenser, it is not necessary to adjust the circulating water supply, as the adjustable leak alone can control the vacuum.

A barometer kept in the foremen's office has a very carefully made scale, and by a Vernier attachment, readings to 1-100 of an inch can be made.

When electric tests are made, it is essential with alternating current that the load shall be non-inductive. To provide such a load, a water rheostat is provided. This rheostat consists of three wooden tanks about 10 ft. long by 3 ft. wide and 3 ft. deep, of about 1,500 gallons capacity, placed in a small addition to the main shop, as shown as S, Fig. 3. These are filled with water and have iron electrode plates inserted, the number of plates required to be used in a given instance being decided by the current to be carried. The terminals of the generators are connected to these plates by cables. After the water becomes thoroughly heated to constant temperature by passing current through it, the load can be regulated by the spacing of the plates. Sometimes with low voltages and heavy currents, salt has to be added to the tanks to reduce the resistance in order to properly apply the load.

Before any tests are made, all test apparatus is carefully calibrated. The steam gauges are tested by a Crosby Gauge Tester. Known standard weights are applied to the plunger of a hydraulic

oil system to which the gauge is connected and readings taken on the gauge to be calibrated. If the pointer reads several pounds out, it is taken off and re-set. A set of readings at increments of 5 or 10 pounds is taken of the standard and the gauge, with pressures from 0 to the limit of the gauge, and a record made for use later on.

Thermometers are usually calibrated in their respective mercury cups on the engine after the engine is started, but before the

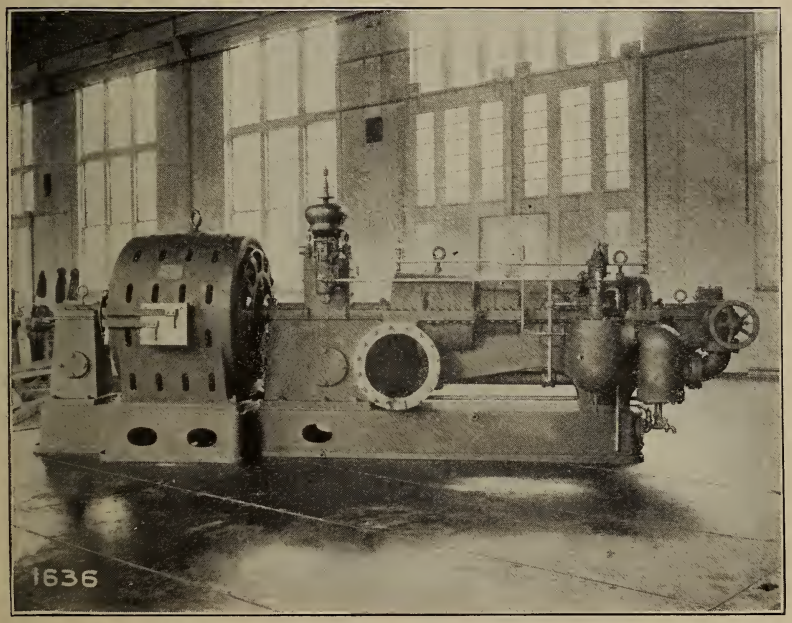


Fig. 8.—400 K. W. Steam Turbine Complete.

test is begun, so as to have a current of steam about them. A steam gauge which has been already calibrated is attached beside the thermometer cup. A series of simultaneous readings of gauge and thermometer is made. The readings of the gauge are corrected to standard. The barometer is noted, and from a set of steam tables the theoretical temperature is found. From these readings an average correction is found to be added to, or taken from the readings

of the thermometer. Gauges are generally calibrated both before and after the test in order that errors due to overheating or other causes during the tests, may be accounted for.

When tests with the generators, which are constructed by the Westinghouse Electric & Manufacturing Company, are made, engineers from their test floor are sent over to take charge of the electrical loading and measurements. These engineers bring their own instruments, which are always calibrated before being brought over. With voltmeters and ammeters, a table showing their readings compared to standard, is supplied. A curve usually accompanies a dynamometer.

Let us now suppose the steam turbine to be tested, is already assembled on the test floor; all adjustments made and the generator or water brake connected up. A preliminary run is made to see that all parts are free and in running order. During this run, the thermometers are calibrated. Then load is put on for a governor test. With a water brake the load can be gotten on in a few seconds, but with a generator, much time is taken in heating tanks, adjusting plates, etc. In fact generator tests, except on larger sizes, are now only rarely made. Full load is put on and minute readings for five minutes are taken on the continuous counter. Also minute readings of load are made. The conditions for the five minutes *i.e.,* the steam pressure at the throttle, at high pressure inlet and the vacuum are noted. Between full load and no load a number of loads are taken that will give sufficient points for a good curve, and these readings taken for each load. Then from the readings of the continuous counter, the speed is calculated and a curve is drawn, whose co-ordinates are, load and speed. From this curve the total governor variation is found and the governor regulation over different loads can be seen. This curve is very useful after the engines are installed, especially if they are to run in parallel with other engines.

The next step on large engines is to set the small centrifugal governor that controls the automatic throttle. This is usually set so that with a 10 per cent. increase in speed, it will shut the engine down.

When an automatic secondary valve is provided, load is added until this commences to open. The load at that instant is noted and a record made in the tests.

Before being sent to the Steam Turbine Department, all generators are thoroughly tested at the Westinghouse Electric & Manufacturing Company. In the steam turbine tests, the generators themselves are not tested, but simply form a means of loading the engine. At the Electric Company, after assembling, the generator is run up

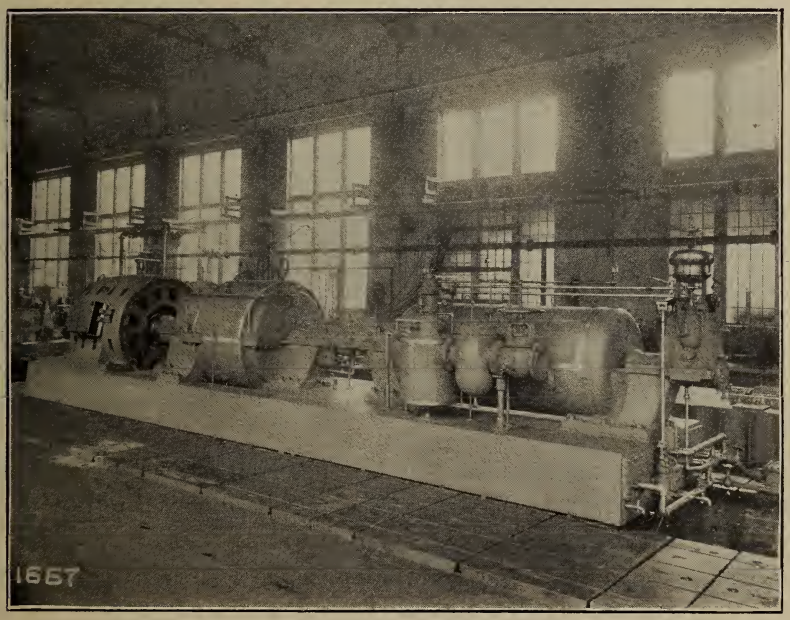


FIG. 9.—750 K. W. STEAM TURBINE COMPLETE.

to speed and a running balance of the revolving field is made. Then it is given a high speed test at 20 per cent. over normal speed, for defects in material. It can now be connected up for electrical test. An insulation test is made. The resistance cold is taken and the resistance hot is also taken later on as after a temperature run. From these readings the copper loss is calculated. Saturation and iron loss tests follow. Next the generator is short-circuited and

readings taken with different field charges. From these readings the regulation is calculated. A test is also made to determine the friction and windage. Finally a temperature run with 7-6 field charge is made. This test will continue until the temperature becomes constant, usually from 5 to 10 hours. A rise of 40° C. above the atmosphere is the highest allowed. From these tests a commercial efficiency curve is calculated.

The steam turbine is now ready for economy tests. The purchaser usually wishes to have tests of his engine made with conditions as near as possible to those it will operate under, *i.e.,* same boiler pressure, superheat, if any, and vacuum. The Westinghouse turbine testing plant, by the flexible arrangement of its apparatus, can supply all these conditions except boiler pressure, where this exceeds 160 lbs., the limit of the boilers. Lower boiler pressures can be had by lowering the safety valves on the boilers. Each engine then is tested under a given set of conditions, as specified in the contract of sale. The vacuum is usually stated as so many inches of mercury referred to a 30 in. barometer. As the barometer here is never up to 30 in., the vacuum as shown by the mercury column attached to the exhaust must be corrected to the observed barometer. During a test the vacuum is controlled by the method already described.

Test sheets are provided for four observers, which are "Temperature and Pressure Sheet," "Electrical Readings," or if it is a brake test, "Brake Readings," "Condensed Steam Weights" and "Gland Leakage Sheet." When testing on the smaller floor the man who regulates the superheater, takes the readings of it on an extra sheet. Tests are usually one hour runs. On the brake sheet, readings are taken every minute. The condensed steam weights are taken either every five or ten minutes according to quantity. On the other sheets, readings are recorded at the start of the hour and every five minutes after.

On the "Pressure and Temperature" sheet, as shown in sample test, Fig. 12, records are made of the simultaneous readings of the boiler pressure and temperature at the superheater; the simultaneous

readings of the throttle pressure and temperature; the high pressure inlet pressure; if a two cylinder engine, the high pressure outlet pressure and low pressure inlet pressure; the vacuum as shown by the mercury column; the simultaneous readings of steam pressure, back pressure in inches of mercury, and temperature at the calorimeter, if used; the barometer; and the speed as shown by the continuous counter, tachometer or hand counted strokes for a minute. What is known as "high pressure inlet pressure," is the average

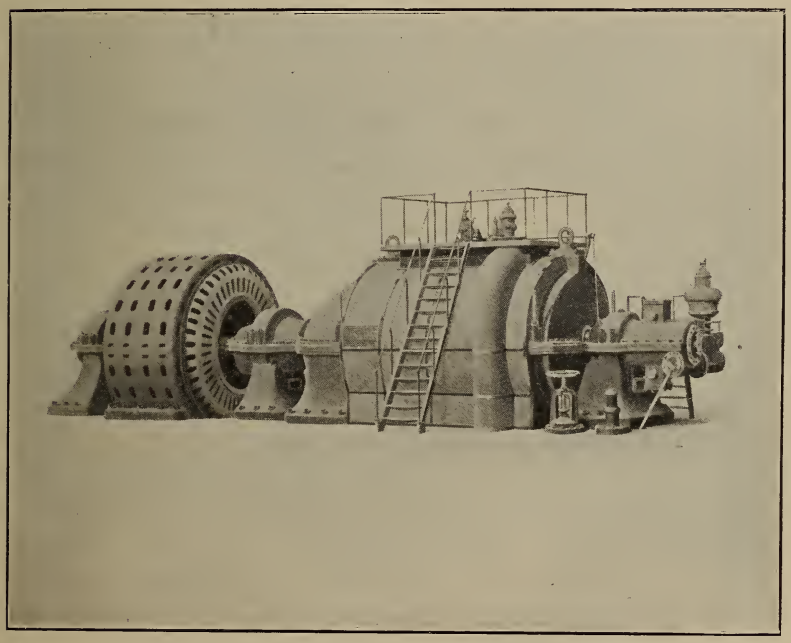


FIG. 10.—5,500 K. W. STEAM TURBINE COMPLETE.

pressure, as shown by a gauge, of the steam after it has passed through the poppet valve and before it enters the blades. This pressure varies with the load. The speed is either held at the rated speed for all tests, or is set to give the rated speed at some given load and allowed to vary for other loads as shown by the governor curve.

On the electrical sheet are entered the dynamometer readings for each phase; the ammeter readings for each phase, if taken; the voltmeter readings, and readings of voltage and current for the field. A sample sheet is shown in Fig. 12.

The brake sheet as also shown in Fig. 12, states the brake number, the radius of the brake arm and the dead weight of the brake on the scales. The total scale weight at the end of every minute is taken during the whole test. The dead weight is accurately found by placing the shaft with the brake on knife edges and weighing on the scales used in test. All weighing scales used on the testing floors are tested frequently.

For condensed water, a gauge glass has been placed on the hot well so as to indicate the height of the water inside. The dead weight of one of the weighing tanks is taken before the test starts. On the second for starting the test, the three-way cock is thrown to allow the water to run into the set tank only, and at the same time an indicator is set at the level of the water in the gauge glass on the hot well. The dead weight of the other tank is taken and at the end of five minutes the water is turned into it. The total weight of the first is then found and by subtracting the dead weight, the net condenser discharge for five minutes is found. At the end of the hour the height of water above or below the indicator on the hot well gauge glass is noted, and a correction for the weight of the water that has been pumped out or should be pumped out, is made to the net weight of condenser discharge for the hour. After an engine has been tested, the main exhaust line is completely blanked off from all engines; water is circulated through the condenser and a vacuum carried by the air pump equal to that called for in the test. Any leakage in the condenser tubes collects in the hot well and is pumped over and weighed. This is known as "condenser leakage," and as a correction must be subtracted from the net condenser discharge.

Leakage of air from the atmosphere into the exhaust spaces of the casing where the shaft passes through, is prevented by water-sealed frictionless packing glands. No oil is used, so the condensation from the turbine is pure water.

After all these corrections have been made to the net condenser discharge, the remainder will be the actual weight of condensed steam required by the engine to carry the given load for one hour, under the given conditions. A sample condensed steam sheet is shown in Fig. 12.

On 400 K. W. turbines usually only three tests are made, one a little over full load, another at $\frac{3}{4}$ load and a third at slightly less than $\frac{1}{2}$ load. On the larger engines, four is the usual number of

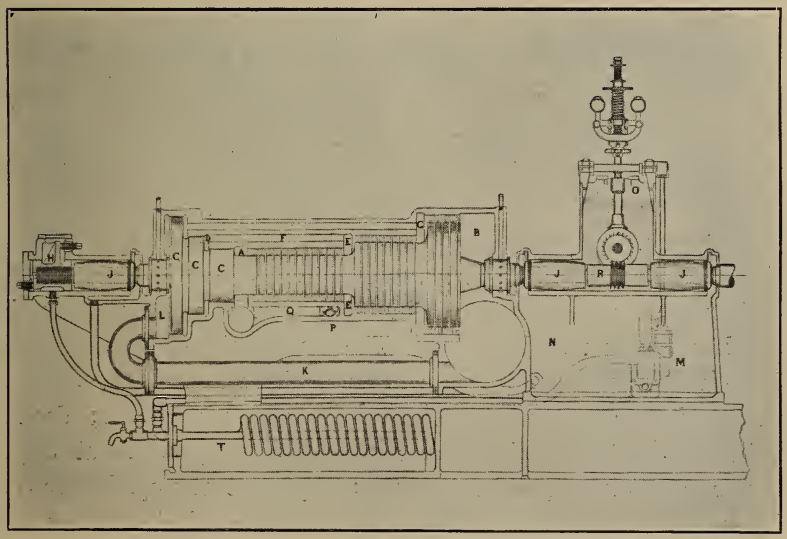


Fig. 11.—Section of 400 K. W. Steam Turbine.

tests; one at 50 per cent. overload, a second at full load, a third between $\frac{1}{2}$ and $\frac{3}{4}$ load, and a fourth at $\frac{1}{4}$ load.

After the tests have been made, the readings are collected and worked up. The first step is to write up, in suitable blanks, copies of all calibrations, and from these the corrections for each instrument or thermometer is found. The readings on the Pressure and Temperature sheet, are averaged and corrected from the calibrations. From the corrected boiler pressure and the corrected temperature at the superheater outlet, we can find, with a set of steam tables,

the superheat at the superheater outlet. A column, as shown on sample test, Fig. 12, is provided for these values. From the throttle pressure and temperature, we can find the superheat at the throttle, if any. From the calorimeter, the quality of the steam can be ascertained. Columns are provided for these on the sheets as shown, but it is customary only to obtain the superheat and quality from the averages for the hour, though sometimes, on special tests, these are figured for every five minutes. The average speed of the engine can be found from the readings of the continuous counter, or the counted strokes.

The electrical readings are averaged and corrected for calibrations, and the load calculated. Similarly, brake readings are averaged, the dead weight subtracted and the load calculated, using the speed as shown on the pressure and temperature sheet. The total steam consumption has already been found as shown by the condensed steam sheet.

On the inside of the cover, is a general summary of the test, as shown in sample test, Fig. 12. All results are those shown on the different other sheets. All calibrations must be allowed for so that all data are corrected results. The statement includes:—Throttle Pressure in pounds per square inch; High Pressure Inlet Pressure, in pounds per square inch; Vacuum by mercury column; Vacuum referred to 30 in. barometer; Barometer; Temperature at Superheater Outlet in degrees Fahrenheit; Superheat at Superheater Outlet in degrees Fahrenheit; Temperature at Throttle in degrees Fahrenheit; Superheat at Throttle in degrees Fahrenheit found either from the average of the superheat for each reading, or calculated from the calorimeter quality when the test is intended for dry steam; Quality of entering steam; Speed as shown by continuous counter; Tachometer or hand counted strokes; Load in Brake Horse Power, or if an electrical test, in Kilowatts and Electrical Horse Power; the Total Steam condensed in pounds per hour; Pounds of Steam per Brake Horse Power per hour; and Pounds of Steam per Electrical Horse Power per hour, as the Electrical Horse Power is the standard by which the engines are sold. The Brake Horse Power rate is transferred into an Electrical Horse Power rate by

referring to the curve showing the commercial efficiency of the generator.

Then from the results of a set of tests, a steam consumption curve is drawn whose co-ordinates are load and total pounds of condensed steam per hour, and from this, another curve whose co-ordinates are load and pounds of steam per horse power per hour. One of these curves is shown in Fig. 13.

It may be interesting to note that the sample test, Fig. 12, is an original set of readings for one of the official tests of a 400 K. W.

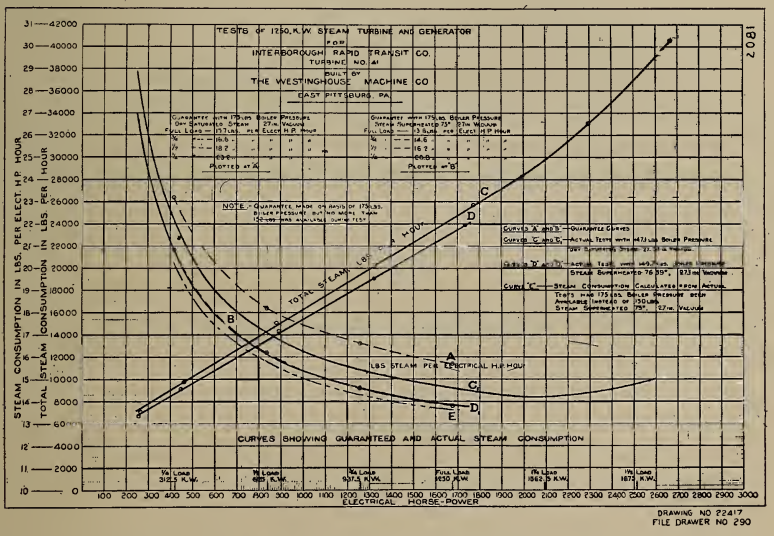

TESTS OF 1250 K.W. STEAM TURBINE AND GENERATOR
FOR
INTERBOROUGH RAPID TRANSIT CO.
TURBINE NO. 41
BUILT BY
THE WESTINGHOUSE MACHINE CO
EAST PITTSBURG, PA.
NOTE - GUARANTEES MADE ON BASIS OF 175 LBS. BOILER PRESSURE BUT NO MORE THAN 150 LBS WAS AVAILABLE DURING TEST
CURVES 'A' AND 'B' - GUARANTEE CURVES
CURVES 'C' AND 'D' - ACTUAL TESTS WITH 173 LBS BOILER PRESSURE
CURVE 'C' - STEAM CONSUMPTION CALCULATED FROM ACTUAL TESTS WITH 175 LBS. BOILER PRESSURE DRY AND SATURATED STEAM SUPERHEATED 73° F. 27 IN. VACUUM
TOTAL STEAM LBS. PER HOUR
LBS STEAM PER ELECTRICAL H.P. HOUR
CURVES SHOWING GUARANTEED AND ACTUAL STEAM CONSUMPTION
STEAM CONSUMPTION IN LBS. PER ELECT. H.P. HOUR
TOTAL STEAM CONSUMPTION IN LBS. PER HOUR
ELECTRICAL HORSE-POWER
1807
DRAWING NO 22417
FILE DRAWER NO 290

FIG. 13.—STEAM CONSUMPTION CURVES FOR 1,250 K. W. STEAM TURBINE.

steam turbine, now installed at the works of the Sherwin-Williams Company at Cleveland, Ohio. The results show the remarkably low steam consumption of even this small size of steam turbine. To compare with reciprocating engines, it is necessary to transfer this rate into pounds per indicated horse power. Assuming, as is usual practice, that the mechanical efficiency of the water brake and steam turbine combined is 85 per cent., the steam consumption becomes

10.03 pounds per indicated horse power per hour. This bears more than favorable comparison with any reciprocating engine yet built. Fig. 13 shows the steam consumption curves for a 1,250 K. W. steam turbine for the Interborough Rapid Transit Company of New York. These curves show that the actual performance of the turbine was much better than that guaranteed, which itself was unusually low.

Gland Leakage sheet records the amount of water that is drawn into the exhaust end of the engine through the gland, which is water sealed. This can be very accurately weighed by a very complete outfit installed as at Fig. 3. It is usually 100 lbs. per hour. Here it is abnormally high. Steam consumption rates are among the best yet made on any engine whatever.

In conclusion, I wish to express my indebtedness to The Westinghouse Machine Company for their kind permission to present this paper discussing their plant and methods; and also for supplying me with photographs, curves, drawings and the original test, which accompany this paper.

On the following pages is reproduced the original Westinghouse report of the steam turbine test referred to in the paper.

Fig. 12

STEAM TURBINE TESTING DEPARTMENT.
THE WESTINGHOUSE MACHINE CO.
EAST PITTSBURG, PA.

Official Test.

400 K W. ..... Volts ..... Phase 3600 R. P. M
for
Sherwin-Williams Co
Cleveland, O.

Load Full
Superheat 150°
Vacuum 28"

TURBINE No. 54
TEST No. 2
DATE Dec. 18/03.

STEAM TURBINE TESTING DEPARTMENT.

THE WESTINGHOUSE MACHINE CO.

East Pittsburg, Pa., Dec 18 1903

TEST No. 2 TURBINE No. 54

400 K.W. Volts Phase 360.0 R.P.M.

TIME FROM 11.25 A.M. TO 12.25 P.M.	
Throttle Pressure Lbs. Gauge per Sq. In.	150.6
H. P. Inlet Pressure Lbs. Gauge per Sq. In.	119.2
Vacuum in L. P. Outlet by Mercury Column	27.6
Vacuum referred to 30" Barometer	28.
Barometer	29.6
Temperature at Superheater Outlet °F.	595.2
Superheat at Superheater, °F.	227.5
Temperature at Throttle, °F	504.8
Superheat at Throttle, °F.	138.9
Quality shown by Calorimeter	
Speed shown by Continuous counter	3537.5
Load in Brake Horse Power	624.15
Load in Kilowatts	
Load in Electrical Horse Power	
Total Net Lbs. Steam Condensed	7368
Lbs. Steam per B. H. P. Hour	11.80
Lbs. Steam per E. H. P. Hour (calculated) from gen. eff.	12.82
Official Test.	
Lbs. Steam per I.H.P. Hour (calculated)	10.03

Calculations made by A. G. Christie
SIGNATURE.

NOTE—The above must be corrected results and all calibrations allowed for.

REMARKS.

Was unable to get 150°F superheat with the superheater on account of gas being low.

Excessive gland leakage due to poorly adjusted gland which did not show up till test started. Was re-adjusted when test was over.

A. G. Christie

Fig. 12.

STEAM TURBINE TESTING DEPARTMENT

THE WESTINGHOUSE MACHINE COMPANY.

East Pittsburg, Pa., Dec 18 1903

TURBINE No. 54 TEST No. 2

400 K.W. 3600 R.P.M. H.P.

PRESSURE AND TEMPERATURE READINGS.

Time.	Boiler Pressure.	Throttle Pressure. B	H.P. Inlet Pressure.	H.P. Outlet Pressure.	Vacuum by Mer. Column	Temp. at Superheater Outlet °F. A	Superheat at Superheater Outlet	Temperature at Throttle. B	Superheat at Throttle.	Steam Pressure at Calorimeter. C	Pressure in Calorimeter in Mercury. C	Temp. in Calorimeter. C	Quality.	Tachometer.	Continuous Counter.	Counted Strokes per Minute.	Barometer.					Int. No.
A.M		141.74	62.16					19														
11.25		148	115	27.5"				494							641235		29.6"					
30		148	117	27.6				496							642075		"					
35		154	120	27.6				498							642916		"					
40		152	120	27.6				498							643760		"					
45		149	120	27.6				498							644605		"					
50		145	120	27.6				498							645445		"					
55		154	120	27.6				499							646285		"					
12.00		154	120	27.6				499							647131		"					
05		147	120	27.6				500							647974		"					
10		150	120	27.6				501							648813		"					
15		155	115	27.6				502							649655		"					
20		149	115	27.6				501							650500		"					
25		153	115	27.6				500							651342		"					
		1958	1537					6484							Difference 10107							
Avge.		150.6	118.2	27.6				498.8		-					16845		29.6					
Calibrations		+0	+1					+6							21:1							Calibration.
Corrected Readings.		150.6	119.2	27.6				504.8	138.9						3537.5		29.6					

NOTE.—Readings in columns marked with abc letters must be read simultaneously.

Signature of Observer. A. E. Christie,

Fig. 12

796-45-12-03

STEAM TURBINE TESTING DEPARTMENT.

THE WESTINGHOUSE MACHINE COMPANY.

East Pittsburg, Pa., Dec 18 1903

TURBINE No. 54 TEST No. 2

400 K.W. 3600 R. M. P.

Nominal Load During Test 400 K.W. 585 B. H. P.

WEIGHTS OF CONDENSED STEAM.

Time. A. M. P. M.	Dead Weight.	Gross Weight.	Net Weight.	Time. A. M. P. M.	Dead Weight.	Gross Weight.	Net Weight.
11.25	—	—	—				
35	1109	2502	1393				
45	1128	2524	1396				
55	1110	2514	1404				
12.05	1129	2546	1417				
15	1110	2518	1408				
25	1129	2525	1396				

Water Level in Hot Well 2½ Inches above below point at commencement of test.

Diameter of Hot Well 24 in.

Net Lbs. Steam Condensed per Hour 7368

Total Condenser Discharge per Hour 8414 lbs.

½ Hot Well Correction −41 lbs.

− Gland Leakage −953 lbs.

Condenser Leakage −52

7368

Signature of Observer J. M. Lee

Fig. 12

1515-294-15-03

STEAM TURBINE TESTING DEPARTMENT.

THE WESTINGHOUSE MACHINE COMPANY.

East Pittsburg, Pa., Dec 18 1903

TURBINE No. 54 TEST No. 2

SUPERHEATER READINGS.

Time. A. M. P. M.	Boiler Pressure #9112	Temp at Superheater Outlet °F #15	Superheat at Superheater Outlet °F			
11 25	151	604				
30	150	602				
35	160	600				
40	157	600				
45	154	600				
50	147.5	602				
55	156	599				
12 00	158	600				
05	152.5	604				
10	151	608				
15	159	601				
20	153.5	599				
25	155	597				
	2004.5	7816				
	154.2	601.2				
	+ 0	−6				
	154.2	596.2	227.6			

Signature of Observer C. J. Parker.

Fig. 12

STEAM TURBINE TESTING DEPARTMENT.

THE WESTINGHOUSE MACHINE COMPANY.

East Pittsburg, Pa., Dec 18 1903

TURBINE No. 54 TEST No. 2

400 K. W. 3600 R. P. M.

Brake No. 3 Brake Radius 20 3/32 ins. Dead Weight 32 #

Nominal Load During Test 585 H. P.

BRAKE READINGS.

A. M. P. M. Time.	Gross Scale Weight.	A. M. P. M. Time.	Gross Scale Weight.	A. M. P. M. Time.	Gross Scale Weight.	P. M. Time.	Gross Scale Weight.	P. M. Time.	Gross Scale Weight.	P. M. Time.	Gross Scale Weight.
11 25	585	1138	580	1151	590	1204	586	1217	577		
26	581	39	580	52	588	05	595	18	586		
27	575	40	578	53	587	06	593	19	590		
28	572	41	581	54	592	07	598	20	590		
29	585	42	572	55	585	08	600	21	588		
30	586	43	583	56	595	09	597	22	585		
31	585	44	581	57	591	10	595	23	581		
32	584	45	594	58	574	11	590	24	585		
33	582	46	585	59	586	12	585	25	585		
34	585	47	587	12.00	582	13	586	26			
35	584	48	587	01	579	14	585				
36	581	49	588	02	578	15	575				
37	583	50	590	03	576	16	575				
	7578		7593		7603		7660		5267		35,701
Average.											

Average Gross Weight 585.2 Lbs.

H. P. = 624.15

Dead Weight -32 Lbs.

Net Weight 553.2 Lbs.

Remarks:

Signature of Observer Wm Kissmodel

Fig. 12. Sample Sheet.

710-3-04 1M.

STEAM TURBINE TESTING DEPARTMENT.

THE WESTINGHOUSE MACHINE CO.

East Pittsburg, Pa., 19

TURBINE No. TEST No.

K. W. Volts Phase R. P. M.

Nominal Load During Test K. W.

ELECTRICAL READINGS.

A. M. P. M. Time.	Dynamometer Readings. 1 Ph. K	2 Ph. K	3 Ph. K	Average Dynamom.	Volts.	K. W.	E. H. P.	Field. Volts.	Field. Amp.			
												Instrument Number.
Avge.												

Notes on Calibration.

Signature of Observer

1043-434-12-08

Fig. 12

STEAM TURBINE TESTING DEPARTMENT.

THE WESTINGHOUSE MACHINE CO.

East Pittsburg, Pa., Dec 18 1903.

TURBINE No. 54 TEST No. 2

400 K. W. Volts Phase 3600 R. P. M.

GLAND LEAKAGE.

Time ~~Noon~~ P. M.	Weight of Tank, Lbs.	Leakage of Glands.	Time A. M. P. M.	Weight of Tank, Lbs.	Leakage of Glands.
11 26	465				
11 40	230	235			
11 40	486				
11 55	243	243			
11 55	470				
12 10	230	240			
12 10	455				
12 25	220	235			

Total Leakage 953

Gland Leakage per Hour 953

Signature of Observer J. W. MacCormick

WIRELESS TELEGRAPHY.

C. A. Chant, M.A., Lecturer in Physics, University of Toronto.

Many people think that wireless telegraphy is purely the product of the last half-dozen years—that it came into full-blown existence when Marconi came upon the scene. But no great discovery is the product of only a day, or a year. Back more than half a century we find Faraday planting the seeds of the "dielectric" theory of electricity, while his great follower Maxwell brought the plant to blossom as early as 1865, when he first clearly stated the electro-magnetic theory of light. Yet it was not until 1887 that Hertz picked the fruit that the world was waiting for. It was in this year that he discovered a method of demonstrating the transmission of electro-magnetic effects through space.

The work thus begun was at once pushed with vigor by men all over the world, and one of the most noted of these was Righi, of the University of Bologna. One of his pupils was Marconi, who was fascinated by the experimenting and who soon began to extend the small space—a few yards—over which effects had been sent.

Righi had invented a powerful radiator for emitting short waves. Half of each of two spheres (fig. 1) is enclosed in an oil-tight vessel, with a small space between them. A knob on each side is attached to an induction coil which causes sparks to pass at the three spaces between the knobs and the spheres. Thus the electrical disturbance is produced and spreads out in every direction.

Now Marconi found that the effects could be observed at much greater distances if one of these knobs was joined to a wire held up

in the air while the other was connected to earth. It was Marconi's view that the waves were generated by the sparks between the spheres, and the attached wires radiated the wave-energy out into space. For a considerable time he was careful to clean the surfaces of the spheres and to keep the oil insulation, but at last he found that the oil and the spheres themselves were entirely unnecessary, and that it was the upright wire, usually called the antenna, which did all the work. Thereafter he used the simplified arrangement shown in fig. 2. A wire runs up from the earth and has a spark-gap near its lower extremity.

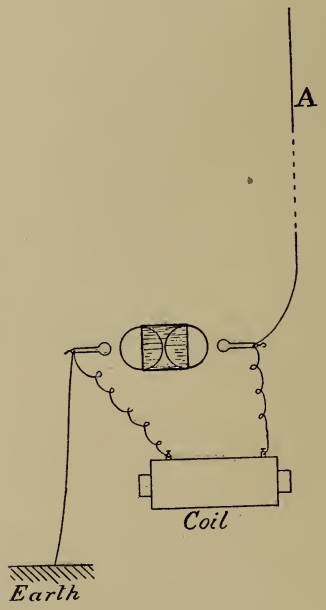


Fig. 1.

The most convenient detector of electric waves consists of a tube containing metallic filings, in circuit with a battery and galvanometer, or other current-detector. The action of the coherer is well known. In its ordinary state the metallic powder is a very poor conductor, but when electric waves fall upon it the resistance decreases in a marvellous manner. This fact was discovered by Branly in 1890;

and Lodge, in explaining the action, said that the particles of metals when acted on by the electric waves seemed to *cohere*, and hence the name Coherer.

Marconi experimented on the coherer and evolved a very sensitive type, in which electrodes are small and close together, and the amount of powder between them is very small. He also discovered that the effectiveness of the coherer was multiplied many times by attaching one pole to a vertical wire and the other to the earth.

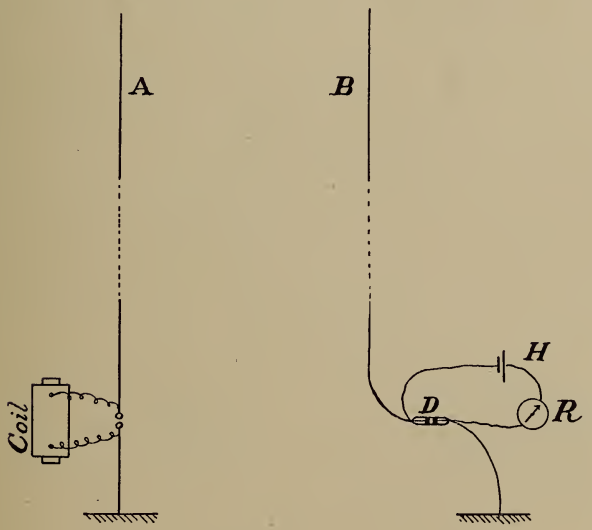


FIG. 2.

Marconi made many successful experiments with his apparatus arranged as in fig. 2, one of the best known being the exchange of messages between France and England in 1899.

Soon after this Marconi introduced great modifications in both transmitter and receiver. These are sketched in fig. 3.

Here A is the transmitting and B the receiving antenna, T the transmitting and J the receiving step-up transformer (or jigger), C the induction coil, *a* the spark-gap, K a condenser, D the coherer, E a choking-coil, H a battery and R the relay.

There are two German systems which have achieved decided success, namely, the Braun and the Slaby-Arco, both systems now being controlled by the same company. In the former the arrangement is very similar to that shown in fig. 3. Indeed Braun is recognized as the inventor of the transformer method of exciting the waves in the antenna.

The arrangement in the Slaby-Arco system is shown in fig. 4, in which the letters have the same signification as in the last figure. One of the distinctive features of this system, however, is the coil S

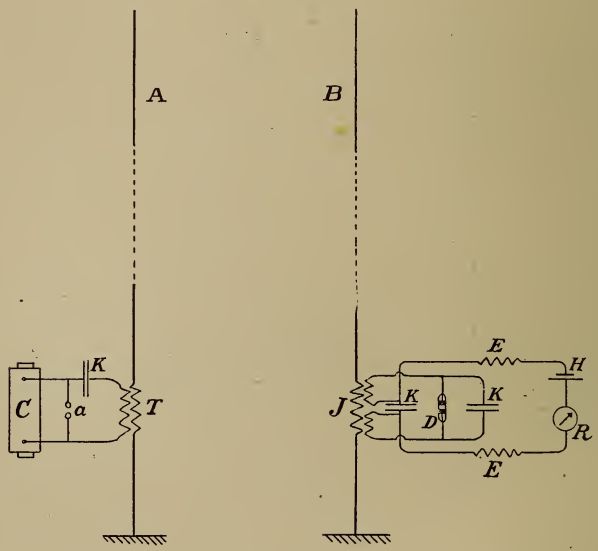


Fig. 3.

at the receiving end. Since the coherer is a device operated by tension rather than by current, the least advantageous position for it is at the bottom of the antenna, near the earth, as the variation of tension there is least, and so a length of wire, S, is inserted equivalent to the antenna. Thus the upper end of the antenna is a loop of potential, and so also is the end *e* of S; but, still further, the wire S is wound so that the tension at *e* is exalted above that at the upper end of B. This coil is called the multiplier.

The two best known American systems are the de Forest and the Fessenden. In the former the transmitter connections are somewhat similar to those of the Slaby-Arco, but the condensers are charged and the spark produced by stepping up the ordinary commercial alternating current through two transformers in series. The receiver is either electrolytic, or simply a steel sewing-needle held across two aluminum wires and joined in series with a telephone receiver and one or two dry cells.

In the Fessenden system there are many original features, one of which is called a "wave-chute," and which consists of a number of

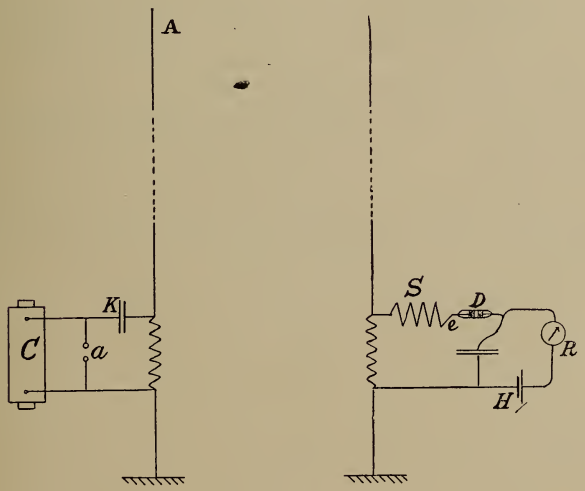


Fig. 4.

wires leading out from the base of the antenna, the object being to assist in projecting the radiation over a poor earth or in a desired direction. Another novelty is the receiver used. To one form, probably electrolytic in its action, its inventor has given the name of liquid barreter. It is declared to be several hundred times as sensitive as the coherer.

From figures 3 and 4 it will be seen that the usual method is to produce oscillations in a closed circuit containing a condenser, the

energy being handed over to the antenna either by inductive action (fig. 3), or by direct connection (fig. 4), while in the original Marconi system the spark-gap is directly in the antenna. For some time I have been attempting to determine the nature of the disturbance about the antenna, and though a full account of the investigation cannot be given here,* some general results may be stated.

In the original Marconi method the oscillations are chiefly those due to the wire as a whole, the wave-length being four times the length of the antenna. In the directly-connected method (Slaby-Arco) the effect is very similar, the oscillations of the condenser circuit being only secondary. On the other hand, in the inductive method the most prominent feature is the oscillation of the condenser circuit which is clearly forced upon the antenna, the oscillation proper to the antenna itself being of small account.

The research is being continued, with especial reference to the receiving antenna.

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* See American Journal of Science, Jan., 1904, or Philosophical Magazine, Feb., 1904.

ENGINEERING IN INDIA.

T. L. Walker, M.A., Ph. D., Professor of Mineralogy,
University of Toronto.

On February 3rd Professor T. L. Walker addressed the Society on Engineering in India.

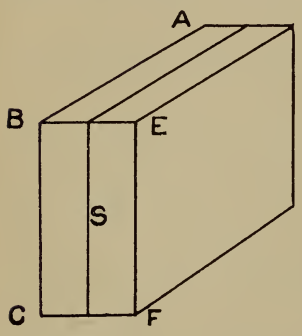
For the purpose of training officers for the leading posts in the engineering branches of the Indian public service the Government has established the Indian Engineering College at Cooper's Hill, near London, where specially selected candidates are admitted to study, and after a three years' course of instruction the successful students are sent out to India. Most of these recruits enter the Public Works Department, the others being assigned to either the Forest or Telegraphic branches. Apart from Cooper's Hill there are numerous state schools for the training of natives and others in India, especially for the subordinate positions of the service. The men occupying the important appointments are mostly from the British Isles, though any subject of the Empire is eligible regardless of race or place of birth. The pay is ample. Leave of absence is permitted every few years and after about twenty years' service the Indian state engineer may retire while in his prime on a modest pension.

A number of lantern slides were shown illustrating the work of the native in the construction of roads, bridges and public buildings.

A NEW PHOTOMETER.

W. J. Loudon, B.A., Associate Professor in Physics,
University of Toronto.

The photometer which I have devised is made of two pieces of specially prepared paraffin, each about one inch square and one-eighth of an inch in thickness. ABC, DEF, separated by a very thin metallic reflecting surface. S, which, while preventing the passage of rays from one side to another, reflects them, thereby increasing the illumination of the paraffin.



The disc thus formed is placed within a suitable box, blackened on the inside to prevent internal reflection; and the face BCFE is viewed through a telescope attached rigidly to the box in front.

The sources of light to be compared are then placed, one on each side of the photometer box, and the light from the two sources passes through openings made in the ends of the box, and falls upon the faces ABC, DEF.

The two surfaces, when viewed through the telescope, will generally present different appearances, owing to the unequal illumination; the box is then moved (or the lights moved) until the two faces are exactly similar in appearance, *and the separating line S has disappeared.*

In this position the ordinary law of the inverse square of the distance follows.

A special arrangement is used to reverse the screen within the box so as to take a second reading, and thus eliminate any errors due to the inequalities of composition of the two blocks of paraffin.

THE RATON COAL FIELD.

E. V. Neelands, B.A. Sc.

Since geological conditions in Ontario afford no opportunities of studying coal deposits in the field, it has occurred to me that a description of the Raton coal field, in which I have recently been engaged, would not be without value. This coal area is of particular interest to Canadians, because of its occurrence in association with rocks similar in age and character to those which prevail over the major portion of our North-West, and in view of the successful development of the Colorado deposits, this may be regarded as a most encouraging fact.

The importance of Colorado as a coal producing State may be judged from its annual output, which is now in the neighborhood of 10,000,000 tons. Of this total the Raton coal field produces over 35 per cent., a large proportion of which appears on the market in the form of coke. This district is situated mainly in Las Animas County, but includes also portions of Huerfano County and northern New Mexico. It has an area of about 800 square miles.

This region was at one time an elevated plateau, gently sloping to the eastward, but at present owing to the erosion of rivers and streams it is deeply intersected by a series of broad valleys and canyons, whose beds in many cases are thousands of feet below the level of the ancient plain. Where protected by lava cappings or spared by the selective action of the rivers, portions of the plateau yet remain, forming the flat-topped mesas so characteristic of the southwest. The sides of these hills, usually almost perpendicular, present ideal stratigraphical sections for the examination of the geologist.

The oldest exposed rocks in the district belong to the Morrison (Jura-Trias) formation, but they are of very limited extent and of no economic importance. The older formations of the Cretaceous-Dakota, Graneros and Greenhorn, are not represented, but as they

occur both to the east and west, they doubtless underlie the whole region. At the beginning of the Cretaceous a profound subsidence had taken place and these formations were deposited under marine conditions. Subsequent to their deposition, and under like circumstances were successively laid down the Carlile, Timpas, Apishapa, Pierre, and Trinidad sandstone formations, all of which are represented by important outcrops in the district.

The Trinidad sandstone is of especial interest as it is the last marine formation of the Cretaceous, and immediately above it lie the coal-bearing strata of the Laramie. This sandstone is prominently exposed along the eastern edges of the foot-hills, and varies in thickness from 150 to 170 feet. It consists of a basal zone of dark grey, fine-grained sandstone layers, separated by thin partings of shale and an upper zone of massive brownish sandstone. In the upper zone occurs the fossil Halymenites, the corn-cob-like stems of which are abundant.

The succeeding Laramie epoch was characterized by shallow waters connected with the ocean. Subsidence continued but to a lesser extent, and the rates of subsidence and sedimentation varied with respect to each other. When the former exceeded the latter the water was deep enough to admit of tidal action, and sandy deposits resulted. When the reverse was the case the currents were obstructed, and silt-like material was deposited. At times extensive swamps and marshes were formed, which supported a dense growth of semi-tropical vegetation, such as exists in the Gulf States to-day, and resulted in the formation of large deposits of Oligneous matter. This series of conditions, several times repeated, the deposits meanwhile slowly consolidating, produced the alternating sandstone layers and coal-bearing shaly beds of the Laramie formation.

Owing probably to erosion before it was protected by the succeeding Eocene formation, the thickness of the Laramie varies from about 1,500 feet in the northern part of the district, to about 2,000 feet in the southern. Upon the Laramie lie the successive Eocene and Neocene formations—Poison Canyon, Cuchara, Huerfano, and Nussbaum. Together they have a maximum thickness of 3,000 feet.

Towards the close of the coal-bearing period a general elevation of the region took place, culminating towards the west in the formation of the Sangre de Cristo mountains, and inaugurating the present

system of drainage. The uplifting of this range was accompanied by a great flexure of the strata along its eastern base, which, combined with the subsequent erosion, resulted in the exposure of the lower Laramie strata and also of part of the Trinidad sandstone. Thus the coal measures appear as a synclinal trough, the centre of which is overlaid by many hundred feet of later deposits, and whose uplifted ends are exposed on the slopes of the mountains and also outcrop at the edges of the foot-hills 40 miles to the east.

Subsequent to the formation of this trough was inaugurated an era of igneous intrusions and eruptions, which continued to manifest themselves almost to the present time, and gave rise to a grand system of dikes which intersects the whole country. When unable to reach the surface the intrusions spread laterally through the sedimentaries, and are evidenced by the high dip of the latter at such points. These rocks are of especial interest, not only because the heat radiating from them, combined with the effect of the profound and long continued orogenic movements, resulted in a general debituminization of the coal, but also because their geological sequence tends to support the current theory of magmatic differentiation. According to this theory the related rocks of a district take their origin from a deep-seated molten magma of medium composition, and as differentiation advances and material is intermittently erupted, its composition at any stage would be more acid or basic than that of the previous eruption according as the character of the associated disturbance influenced the outbreak. That this theory is substantiated may be seen from a consideration of the order of the eruptions—early monzonite-porphyry, early lamprophyre, late monzonite porphyry, late lamprophyre, augite-diorite, augite-granite, granite-felsophyre, granite-porphyry, and basalt. Thus if the early monzonite-porphyry is assumed to have had much the same composition as the original magma, the succeeding late monzonite-porphyry and early lamprophyre are respectively more acid and more basic than that magma, and later continued differentiation resulted in late lamprophyre and finally basalt, having granite-porphyry and granite-felsophyre as their opposite extremes. These rocks were determined both by observation in the field and from the examination of numerous thin sections. Owing to their superior hardness the dikes usually stand high above the

surrounding country, and several of them can be traced for at least 60 miles.

The effect of these igneous rocks upon the coal is of the greatest importance, as in their absence it usually remains in the form of lignite, containing a large amount of water and useless for coking purposes. Pressure due to overlying rocks or resulting from movements in the earth's crust does not appear sufficient in itself to accomplish the alteration of this lignite to a true coking coal, though its influence tends to better the quality. The position of the intrusion, with regard to the coal deposit, and also its nature are of great importance. If the igneous material cuts cleanly through the coal at a high angle, its effect is only local; it alters the coal to natural coke for perhaps 30 feet on either hand. If, however, it is injected along the coal-seam the result is disastrous, as it completely destroys all coal with which it comes in contact. An interesting example of this phenomenon came under my observation at the property with which I was particularly associated. The coal-seam outcrops along some miles of the western slope of a mountain, and at the point of exposure dips towards the east at an angle of 35 degrees. Half a mile east the strata are approximately horizontal. At the point where the alteration of the dip occurs was instituted a line of weakness, along which a basaltic intrusion rose, and having reached the coal-seam roughly followed it to the surface. The basalt outcrops on the hillside in an irregular line, sometimes above and sometimes below the coal; it crosses the latter at least seven times within a distance of three miles. Where the igneous matter lay at a distance of 20 feet above or 50 feet below the coal, the latter is excellent in quality, but where it lay within a few feet or was actually present in the seam natural coke resulted. This coke occurs in coarse prismatic forms, whose longitudinal axis is perpendicular to the source of heat; it lacks the semi-metallic lustre of the artificial product, and has no commercial value.

That the heat due to the intrusions is necessary to produce the alteration of the original lignite to a true bituminous coking coal may be seen from the fact that in the northern part of the field, where this influence was not a factor, the coal is all of the non-coking variety. Also in some parts of the region portions only of a seam have been thus acted upon; these portions now afford coking coal while that

produced by the rest of the seam is altogether wanting in that property.

The coal-beds of workable thickness in this district may be divided into four groups, all of which occur in the first 1,100 feet of the Laramie formation. The lower group includes a series of seams, which vary considerably in thickness in different parts of the district. Usually where this portion of the formation is exposed a seam from 5 to 10 feet wide may be found. This group is known locally as the Berwind-Aguilar, and its seams are not found more than 100 feet above the Trinidad sandstone. The coal is of excellent quality, and mines working on this system of seams supply the great bulk of the output from this region.

About 200 feet above the basal sandstone is the second or Sopris group. Here again there are several seams, but this group is mined at only one point. As a rule the coal contains a few thin "partings" of shaly material; some of it is impure, but the bulk of it breaks out in large rectangular blocks, and is above the average in hardness for coking coal.

The third group lies between 750 and 800 feet above the base of the measures; it includes three well defined seams which vary in thickness from 12 inches up to 10 feet. One of these seams is mined at Primero, where the workable bed has a width of about 7 feet. There are a few streaks of bony material in this coal, and in places about one-half inch of clay, but on the whole it is slightly superior to that obtained from the lower groups. In the southern part of the district the coal from this group is all of the coking variety, but in the north it does not coke unless in the vicinity of an igneous intrusion. The fourth group is about 1,100 feet above the Trinidad sandstone, but it is not regarded as of commercial importance; it affords no "high coal" (coal over 4 feet in thickness) that is not intermixed with shale, and only in a few cases does it contain clean seams of "low coal."

In all these groups the coal usually rests upon shale, though frequently the latter is a mere scale, separating the coal from the sandstone. When the seam is thick the roof is generally shale, but it often happens that sandstone is found above any point where there has been a pinching of the vein. Thin bony streaks are usually present;

if they occur near the top the effect is to make the coal adhere strongly to the roof; if near the bottom they cause the coal to "freeze" to the "floor," making it hard to undermine. Natural coke is frequently encountered.

The general composition of the Raton coals may be observed from the appended list of analyses. In the non-coking coals of the north the moisture generally exceeds 2 per cent., the oxygen is rarely below 7 per cent., and the carbon seldom above 75 per cent. On the other hand, in the southern coals the moisture rarely exceeds 2 per cent., the oxygen is usually below 7 per cent., while the carbon generally exceeds 75 per cent. It will be observed that these coals are rather low in nitrogen, the constituent that is depended on to form ammonia in by-product coke ovens.

Most of the mining is done on the "pillar and stall" system; gangways are driven, and when the seam is horizontal "rooms" are turned off from cross entries on both sides. If the seam dips they are turned off only towards the "rise." The "long-wall" system is sometimes used where the coal is "low" and conditions are favorable. The haulage between the "rooms" and the engine roads is done mainly by mules. Large fans are used for ventilation, but the mines are comparatively free from explosive gases, open lights being in general use. At mines producing coke coal the produce is sometimes shipped as "run of mine," but usually the slack is separated by screening and sent to the coke ovens. The non-coking coal is screened to various sizes for domestic and other uses.

A large amount of the slack or smaller sizes of the coal is made into coke. It is first washed, either by jigging or on bumping tables, to remove the impurities. The washed coal is then charged into beehive ovens, the charges ranging from $3\frac{1}{2}$ to $6\frac{1}{2}$ tons. The oven door is bricked up, small openings being left to admit sufficient air to produce the requisite amount of combustion, and the charge is allowed to stand for from 48 to 72 hours, according to its size. At the end of this time the coke is cooled with water and withdrawn. The coke made from washed coal is found to contain about 3 per cent. less ash than that made from unwashed, and it is much less liable to break up. As it is extremely low in sulphur it is excellent for smelting purposes, and steel of good quality is made by its use at Pueblo.

ANALYSES OF COALS.

Group	Carbon Fixed	Carbon Combined	Hydrogen disposable	Hydrogen with oxygen	Oxygen	Nitrogen	Sulphur	Moisture	Ash	Volatile	Net calories	Specific Gravity
I.....	57.87	16.08	3.39	1.19	9.51	1.28	0.42	1.21	9.05	31.82	69.16	1.320
I.....	54.81	24.41	4.53	0.91	7.30	1.46	0.59	1.24	4.57	39.20	76.92	1.274
I.....	49.98	17.38	4.60	1.07	8.58	1.21	0.40	1.08	15.70	33.24	67.48	1.360
II.....	58.40	20.45	4.87	0.59	4.86	0.99	0.60	0.52	8.90	32.18	77.83	1.318
III.....	59.19	17.55	4.21	0.77	6.21	1.06	0.61	1.63	8.77	30.41	74.02	1.358
III.....	48.83	21.01	3.62	1.36	10.84	1.25	0.47	1.49	11.13	38.53	66.42	1.282

ANALYSES OF ASH.

Group	Silica	Ferric oxide	Alumina	Lime	Magnesia	Soda	Potash	Sulphuric acid	Phosphoric acid
I.....	65.02	7.56	24.73	0.16	0.30	2.22	0.52	0.35	0.095
II.....	60.18	9.12	25.14	1.72	Trace.	2.12	0.78	0.76	0.659
III.....	68.60	6.42	19.94	1.30	Trace.	1.46	1.23	0.34	(with iron)

N.B.—These analyses were made in Denver for the U. S. Geological Survey.

BACTERIAL METHODS OF SEWAGE DISPOSAL.

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Sewage, the liquid contents of a sewer, is made up of human and animal excreta, kitchen, house, personal and clothing washings, and in some cases even street washing. It is not garbage. On an average it contains of solids about 150 parts in every 100,000 parts, or 105 grs. in each gallon of sewage. Only 55 parts of this is made up of organic matter. The rest is mineral. Of the 55 parts half is in suspension, the rest is in solution. The animal solids need no treatment except disposal, the organic solids must be treated (gasified and mineralized, reduced). Such small quantities of course cannot be burned.

Sewage disposal becomes a necessity where the sewage is to be discharged into a possible source of potable water taking. Otherwise the water is poisoned with putrid organic matter, but more seriously through the excreta of diseased animals and men might be made the means of spreading disease (typhoid, cholera, dysentery, etc.). Pure water is as necessary for animals as for men if we wish them to be healthy. The law requires that we do not render the water of a stream passing our door worse below us than it was above us. Where great bodies of water are in consideration the extent of disposal is necessarily not so great as where only small streams are in question. (The sewage is lost in dilution, not always though.) The distance below us at which the water is to be used is often a determining factor in the scheme we are to adopt for the disposal of a sewage in question. We know that nature takes care of the purity of water. The organic

matters that reach a stream, if not in too great quantity, are soon destroyed. Motion, sunlight, oxygen and chemicals in the water are through the agency of certain minute micro-organisms (the bacteria) made use of to do this. The substances are gasified completely, and thus caused to pass into the air, or are partly gasified, the remainder being mineralized, and thus rendered harmless.

The bacteria are present everywhere, they come to water chiefly through the organic matters that reach it. They have extraordinary powers of multiplication, especially if there be food material in plenty for them (just such organic matter as we are dealing with). Where we find many of them in a water it means there is plenty of organic matter there, and where we in addition find many varieties, it shows the multiplicity of kinds of organic matter. These organisms are divided into two great classes, the ærobic and the anærobic, that is, those which need plenty of oxygen for their perfect function, and those which act without oxygen, best where there is none. The ærobic ones oxidize organic substances, the anærobic ones hydrolize those substances.

Albumen, $C_8 H_{13} N_2 O_3 + 19 O = 8 CO_2 + 6 H_2 O + N_2 + H$

Cellulose, $C_9 H_{10} O_5 + H_2 O = 3 CO_2 + 3 CH_4$ (methane)

In these two examples, first albumen by oxidation is converted into carbonic acid gas, water, nitrogen and hydrogen, and second, cellulose by hydrolysis is converted into carbonic acid gas and into methane gas. All of these go off into the air, there is nothing left of either of them. Or, again, the change may not be so direct, as for example:

Starch, $C_6 H_{10} O_5 + H_2 O = C_6 H_{12} O_6$ (sugar).

Sugar, $C_6 H_{12} O_6 = 3 CO_2 + 3 CH_4$

In this example the starch is converted into sugar by hydrolysis, and this again broken up into carbonic acid and methane gases, and thus caused to disappear. All the changes are not so simple as these. Often many changes take place before final gasification. The gases too are not always those named above. Ammonia, sulphides, mercaptans and a host of different gases are formed, but in the end it means the destruction of the organic matter. Now do what we like

with the organic matter, except we burn it, in the end it is disposed of in this way, through bacteria. If we treat chemically we only delay the evil day. We get a precipitate that must be carted away (sludge). We use it as filling material, etc. It will decompose and become less and less, just as a manure pile will in time nearly disappear.

Nature's method of getting rid of organic matter is to decompose it, to rot it, to putrify it, to ferment it, in the end to send it back into the air as gas, and to the earth as mineral matter. The bacteria do this. The anærobic ones by hydrolyzing, the ærobic ones by oxidizing. The hygienic engineer makes use of these minute organisms to do his work, and out of their peculiarities of growth has devised methods to use them to the greatest advantage, and to make them do the work as quickly as possible (septic—rotting—tanks, and oxidizing beds). All the engineer's efforts are directed to making his appliances as favorable as is possible to the development of these peculiarities. Anything that will hinder their growth and function will react against the proper working of any plant devised.

The Hydrolizers. The Septic Tank.—This is really a rotting box, a cess-pool. The anærobes or hydrolizers do their work here. They rapidly gasify and liquify, and thus simplify the compounds (proteids, carbohydrates and fats) of the sewage.

The septic tank is a scientific application of what was found to take place in the old cess-pool. Here it was noted that there ran away from these pools an almost clean-looking fluid, and curiously when they were opened to clean them out, little or nothing was found to remove. Bacteriology explained the phenomena. The organic matter was decomposed and went off as gas and in solution. Simple compounds were formed. These simpler compounds are in turn gasified and further simplified, this being repeated until all is exhausted. The bacteria do this by the action of their ferments. These bacteria come with the sewage. The conditions in the tank are such as to select out those that are anærobic; that is, those that can live and functionate without oxygen. The ærobic or oxygen ones are either killed out or rendered dormant. The sewage in its decomposition uses up a

large quantity of oxygen. There is practically none left free in it. This is why fish die in polluted waters. They are asphyxiated. In the cess-pool there is practically no mixing, so that no oxygen gets down into the depths. What is taken in at the surface is soon exhausted. So soon, in fact, that probably after the first inch there is nothing left. The anærobes have full swing. They are selected out by their circumstantial surroundings. We have bacteria for probably every form of organic matter, decomposable-proteids, carbohydrates and fats. There are left other compounds when the originals have been acted on. This is likely the reason that 50 per cent. goes in the first 24 hours and that it takes 18 to 20 days to decompose the rest. The modern septic tank is run to decompose this first 50 per cent. The rest is left for some other method, and oxidation is that method. It will do in 24 hours what the septic tank will now take, as said above, 18 to 20 days to do.

So that, the septic tank as we understand it now, is chiefly an auxiliary method. Where great dilution of an effluent can be got, this is sometimes now found sufficient (when tide water can be reached or very large rivers not having water supplies taken from them for a long distance below).

There are various gases coming off from a septic tank, viz.:

$$CO_2,\ H_2,\ N_2,\ CH_4,\ H_2S,\ NH_3.$$

There are many others, and some of them very offensive. Ammonia is formed in large quantity from the nitrogenous constituents, but, being so soluble, it is rarely given off. It nevertheless reduces the original constituents.

These gases will burn. In some places attempt has been made to use them for lighting and burning purposes. The supply is so irregular that it is not practical. A very fair percentage of septic tanks produce no offensive odors. It depends on the seeding, and there is no prognosticating what a tank will give in odors, for sometimes one or two in a series will give foul odors, whilst the others nothing noticeable. Where odors of a foul nature are given off, it would be well to cover the tanks, and carry the odors high through a stack. Tanks do as well without covers as with. Scum forms on

some tanks, not in others, and may come and go in the same one. It is simply the organic matter raised by emeshed gas bubbles. But from the surface of the tank-contents in one that is functionating properly a greater or smaller number of large or small bubbles may be seen rising. Of course, sludge collects in these tanks after a time. Some of the less putrescible organic matter and a great deal of mineral matter accumulates. This last depends on whether storm water and road washings get into the sewers or not. This sludge looks like black, more or less granular garden mold. It is for practical purposes all mineral substance, and what organic matter it contains is very simple (wood pulp cellulose chiefly). This has to be taken out from the tank now and then. It is surprising how seldom, though. At Berlin the first chamber was full after four months' continuous running, but there were only a few inches on the bottom in the other four-fifths of the tank; and Berlin sewage held a large quantity of inorganic solids. The sludge, unlike that got by chemical precipitation, is useless as a fertilizer. All or practically all of the organic matter in it has disappeared.

These septic tanks are especially non-exacting as to labor. They run practically automatically. It is found best to run the fluid into them continuously, so that the affluent and effluent are equal; and it is here that the construction of the tank comes in. Three especial functions must be taken into consideration in the construction of the tank. First, decomposition must be favored as much as possible. The tankage must be of sufficient capacity. At Berlin we found it most profitable to make the tanks large enough to hold the whole 24 hours' sewage. This, as compared with 24 hours' capacity in 18 hours, gave 10 per cent. more treatment. And it is much more difficult to get a fifth 10 per cent. than a first 10 per cent., because after all sedimentation has some action, and a considerable one in a working septic tank. If sufficient space is not given the sewage will be washed through too rapidly for a sufficient decomposition to take place in it. Second, the suspended matter must be held. To do this the flow must be controlled, and it is best here to have it enter by a large area under the surface of the tank contents. The large coarser suspended matter will be held back in a grit-chamber. This should be about one-fifth

of the tank capacity. From this the sewage passes into the next compartment over the upper edge of a baffle rising up from the bottom. The other four-fifths of the tank should be baffled up from the bottom some two or three feet about three or four times. The sediment in this way will be held, the larger quantity in the grit-chamber, then less and less as the outlet of the tank is reached. The tank should be made proportionately wide enough and deep enough to allow the fluid to pass through it very slowly, so as to prevent agitation. Third, the scum is to be held. This scum with a general sewage contains oils, floating wood, corks, etc., all damaging to filter beds, the fat especially. This must be retained, and can be easily done by letting down a foot or two from above baffle boards, best on a line with those coming up from the bottom surface.

Provision should be made for cleaning. The outlet end of the tank should be on a higher level than the grit-chamber end. Gates should be put into the bottom of the baffle boards resting on the bottom of the tank, so that when open the sludge will flow towards the grit chamber, and be here pumped out. A bucket pump is best. This sludge can then be spread out on land.

The material out of which the tank is made is of little consequence, so long as it is a durable one. Wood soon crumbles away. The septic tank has several good qualities.

It is a settling basin, no gross solids passing from it.

It liquifies organic matter rapidly and prevents it sludging up the beds.

It reduces half of the organic matter into gas.

It primes the other half so that it can be easily oxidized.

It destroys a great deal of poisonous material, and probably a great many pathogenic bacteria.

It is a very simple plant, requiring only space, and very little at that.

The labor required to run it is very small.

Its disadvantages are few, viz.:

It may give rise to offensive odors, not always. (These may be stacked or burned.) The sludge has to be removed, but this is only

every four or five months. The sludge is useless as fertilizer. When the water is out of it, it is a good filler for waste land. (After the first 24 hours after removal there is very little odor in it, very like moist earth.)

The Oxidizers. Land Treatment. "Land Irrigation."—The first systematic attempt to dispose of sewage on a large scale was made by this method. Large cities like Paris and Berlin had outside their confines extensive tracts of almost barren sandy lands. These lands only needed water and fertilizers to make them productive. These cities were polluting their water supplies with their own wastes. This method of irrigation, as a method of disposal, proved so successful that Berlin irrigated some 11,000 acres of such land, and is extending the system to 19,000 acres.

A daily average of some ten thousand gallons of ordinary domestic sewage can be disposed of to the acre by this method on a suitable soil. The best soil for the purpose is a sand loam, the more sandy the better, and well underdrained, usually at a depth of four feet. Plants take up a large quantity of water from the soil. It is calculated that for every one part of dry solid added to the weight of a plant 250 parts of water are evaporated. But all the water in broad irrigation is not got rid of in this way, but partly by underdrainage. The importance of a porous soil is quite evident when this is taken into account. The more clayey and heavier the land is the less will water drain off, so that if broad irrigation is adopted, where such heavy land only is procurable more must be utilized and very much less fluid applied to the land. All plants are not suitable for growing on such beds, but only such as can be grown on ridges or stand up from the earth are safe to be used as food. The sewage must not touch the plant in its raw stage; this usually injures the plant or may kill it. The plants are placed in beds or ridges, having trenches running around or alongside, in which the sewage courses at intermitting intervals, filtering through the earth, laterally, a good deal of it, of course, sinking down into the earth. Plants cannot use raw sewage, except in very limited amounts. By this method of distributing the sewage, bacteria in the neighboring soil oxidize it, and it is then taken up with the water

which the plants absorb from the earth. Now, plants cannot be loaded day after day with large doses of water. The requirements of the plants by this method come first, and the sewage supply must be limited to these. If there are other beds, and it is always necessary to have plenty of reserve land where this method is used, the sewage is sent to them; if there is not, it must be cast away without treatment. In Berlin, Germany, where this method is possibly seen at its best on the Continent, they have found it necessary to separate the heavier portion, or the sludge, of the sewage, before allowing it to go into the trenches, from the fact that in a very short time this sludge coats over the surface of the trenches and obstructs the filtration into the land, and, from covering the surface, prevents the free access of oxygen into the soil, thereby crippling the action of the ærobic bacteria. Under such circumstances, the effluent from the underdrains is found to carry off a still putrescible, or a more or less incompletely treated and putrescible substance—a poison-carrying material.

At the Asylum for the Insane, at London, Ontario, probably the best broad irrigation method of sewage treatment on this continent is carried on. Heavy crops of varying kinds of vegetables are grown, several crops on the same land being produced in the one season. The sewage is the domestic sewage of the institution, where there are over 1,200 inhabitants, giving about 75,000 gallons per day. This is collected in a large reservoir and pumped out once a day, a special form of steam blower, devised by the engineer, being used to stir up the sewage so that all the sludge is carried off at each pumping. This is distributed to the long beds in lateral ditches or trenches of six feet wide, between flat beds twelve feet wide. The land is coarsely sandy. From the trenches the sewage filters laterally into the vegetable beds. There are seven acres for the treatment of this sewage, and the long beds are centrally underdrained throughout their length. The sludge that collects in the ditches, as soon as it dries, is raked up and carried away in barrows, and this has to be done occasionally, every two or three weeks. The trenches are spaded over three or four times in the year. When more water than ordinarily is required by the plants, and they are of a kind around the roots of which the sewage can be poured, the sewage from the trenches is ladled out. All

this, of course, means a good deal of labor. Here it is useful labor in the treatment of patients, and practically costs nothing. They have found that it is necessary to use manure as well as the sewage to get the best results from their gardening, and this in spite of the fact that it is a fairly strong domestic sewage. There is no bad odor about the place, and no complaints are made from the lower lands. In fact, it is admitted that the crops in the fields below have been better since this system was adopted. During the winter months the sewage is run into the trenches as in the summer, and disappears nearly as quickly, and has given rise to no complaint. The snow, when there is any in the trenches, is dug out before running in the sewage, otherwise they have found freezing takes place to such an extent as to prevent filtration. They leave the snow in the trenches between times to keep the ground from freezing deeply. There are some ten trenches, fully 500 feet long. All the sewage of a day is run into one or two of these and then into the next one or two on the following day, and so on, leaving the first to rest until their turn arrives again. On a recent visit, the trenches had been filled a couple of hours before my arrival. The distal ends were already dry and at the proximal ends the sewage had nearly disappeared. The ground was only moist. These trenches would get nearly five days' rest before the next application. Each trench had got, with this charge, about 37,000 gals. If it were required, more sewage might be treated here by giving three days' rest, on account of the great porosity of the soil and the great care that is taken to keep the surface in such good condition. Land will not treat all it will filter, as is sometimes supposed. The organic matter, as well as a good deal of the mineral, is held in the meshes of the soil. This takes time to decompose and disintegrate. If the sewage were continuously or too often poured on, the spaces would soon be filled or sludged up; treatment would cease, there would soon be hindrance even to the passage of pure water through it.

Now, on account of the fact that the beds are not used to their fullest capacity, from the necessity of favoring the plants grown, and also from the fact that sufficient land is not always available, and that labor to carry on this ideal method thoroughly would be expen-

sive, the method has been further simplified by leaving out the plant-raising end of it. Thus the sewage is poured over the land, the trenches being dispensed with, all parts acting equally. The intervals between applications can be shortened to the capacity of the bacteria's power of disposing of the sewage. Since plants have not to be looked after, all the time can be given to attendance in distribution and keeping clean the land, and the labor may thus be reduced to the minimum. This method is called filtering, and, on account of the intermittency with which the sewage is applied, it is spoken of as "intermittent land filtration."

"*Intermittent Land Filtration.*"—In this method raw sewage is poured over all the land, in intermittent doses, with intervals of two or three days between applications. The higher plants have practically no power of digesting raw material for food purposes for themselves, but bacteria can. It is only the finished product which higher plants use. The finished product is not harmful, so can be run off with impunity. The higher plants obstruct the function and growth of bacteria, so that in this method of intermittent filtration the bacteria are placed in the most favorable circumstances when the land is kept free from higher plant growth. Cropping with this form of treatment is looked on as reducing (according to form of plants grown) the disposal powers of the bed from 25 to 40 per cent. The intermittency is with the object of giving the bacteria between doses a sufficient time to decompose all the organic matter of the last charge We have already seen that, of the organic matters, all are not equally and rapidly decomposable. A point worth noting in the application of the dose of sewage is to do it as rapidly as possible, consistent with non-erosion and serious disturbance of the surface of the beds. The bacteria which do the work in this process are the ærobic ones. If the application be long drawn out, unless in a very fine rain, it cuts off a free oxygen supply, and, as has been seen before, this means crippling the action of the bacteria, and, if long continued, may even kill them out. This brings us to another point with reference to the application of sewage. It is, not to put so much on that it will take more than, at most, five or six hours to sink into the land. For this to be done with uniformity, all matting or caking of sludge on the

surface must be avoided by frequent removal. This is especially necessary if there be much fat or oil or tar in the sludge. These prevent oxygen getting into the soil freely, and if in large quantity may prevent its entrance entirely, as well as preventing the entrance of the fluids of the sewage. The fats will in time decompose, but the tar will not. It is on this account that such substances should be prevented, as much as possible, from getting into filter beds.

The draining of the beds is also important. The products of bacterial action must be carried off if the bacteria are to go on performing their functions. With the land water-logged, the bacteria cease their function. Now, different qualities of land, e.g., clay and sand, vary in permeability. This must be kept in view when dosing sewage beds. Is it clayey? This does not drain well. A very much less quantity of fluid will pass through than will go through sandy land. And so for all intermediate qualities, from sand to clay. The better the capacity for drainage, the less bathing in poisons the bacteria will suffer; the more work they will do. Thus sandy soil is always the best. All lands will treat sewage. But all lands will not treat an equal quantity, or with equal completeness. Not all the fluid that goes through a land is necessarily treated. In clayey land cracks and crevices are often found, especially in dry weather, through which totally untreated fluid may pass.

Bacteria can use up only so much organic matter. The rest is untouched. Dilution has very little effect on the amount of organic matter treated. At the Lawrence Experimental Station sewage was diluted twice and three times with water. The treatment was practically the same in all three sewages. In other words, if a certain area of land will treat the organic matter in 10,000 gals. of sewage, then if that sewage be diluted with an equal quantity of water, thus making it 20,000, the result in organic treatment will be practically the same. This is also the case if it be diluted to 30,000 gals. It is the quantity of the organic matter that counts for most, and not the quantity of fluid. Of course, this must be understood to be within certain reasonable limits. If the sand cannot get rid of the water sufficiently quickly, the organic matter will not be treated at all, or only partially.

At Berlin, Ontario, a process of intermittent land filtration was installed in 1891. As the town grew and the sewage increased in quantity the beds became less and less able to perform their function; they were overworked, water-logged, sludged over the surface, practically all ærobic bacterial action was stopped. These beds became veritable cess-pools. Then, to make things worse, the wastes from tannery after tannery were poured in, also from a brewery, from laundries, and from the gas works. The tanneries increased the organic matter to be treated, added materials like tannins, that are treatable at best only in the smallest quantities under the most favorable circumstances; also sent down fats, as the laundries do from their soaps; and, besides this, a quantity of finely divided bark fibre, which is almost practically non-disposable, being almost non-putrescible. The brewery sends down the husks of grain, and the gas works sends down a tarry oil, which is probably the worst crippler of a disposal bed possible. Altogether, Berlin's 14-acre clay intermittent filtration farm was treated as roughly as was possible. To make things worse still, the surfaces of the beds were not kept clean. One man's labor could not possibly keep the surfaces, under the circumstances, even in fair condition.

To show how hard an old idea dies, with all these circumstances against them—too much sewage, bad filtering material, ill-putrescible substances, objectionable sludging material in the sewage, insufficient labor to keep the surface of the beds free from sludge—an attempt was made, and is being continued, to raise crops on these beds. They raise good crops, but reduce the disposing powers of the beds in a notable degree, when they are already trying to carry a burden twenty times or more than their capacity. (Berlin, Ont.)

To the State of Massachusetts is due the credit of bringing the intermittent land filtration of sewage to its highest development. They have abandoned all other forms of land but sand for the working of this system, so that the process has come to be called "Intermittent Sand Filtration." A considerable quantity of good, well-drained sand can be found almost anywhere in the State. The system has been generally adopted throughout the State, and during the last fifteen

years has done all that was expected of it. It has been perfected in detail, and worked out in theory, until now, of all the methods of treatment of sewage, it is the best, giving effluents not much worse than a good drinking water. In fact, many drink waters are of a much inferior quality. All that is required is a sandy soil or pure sand of four or five feet of uniform thickness. The top earth is thrown up to make banks between one-acre lots. It is drained with ordinary farm tile, four inches in diameter, laid in lines forty feet apart across the bed and leading into a common effluent carrier. A central wooden or cement affluent conveyor is run across the top of the whole bed.

The construction is simple, and comparatively inexpensive. At Brockton, Mass., their farm has been in existence over fifteen years. It has not deteriorated; in fact, it is doing better work to-day than at the beginning. It is treating, the whole year round, an average of 35,500 gals. per acre per day, counting in times of rest, repairs of drains and intermissions. The application to the surface is often 200,000 to 250,000 gals. at one time. They have 25 one-acre beds (19 only are in commission at present), for a population of 30,000 people, all using the sewers. These are used alternately, beginning with No. 1, going on to No. 19, and coming back to No. 1. Each bed thus gets several days' rest between each dose. More could be treated if necessary. But, so far, it has been preferred to buy new beds than to run any risk of sludging up those they have, that are doing such good work.

Essentially raw sewage is being pumped on to these beds. It is collected in a circular reservoir, capable of holding all the twenty-four hours' sewage. Three to four hours' pumping each day is all that is required to empty this. The towns I visited, during my Eastern trip, using this form of sewage disposal, were Brockton, Clinton, Andover, and Hopedale, all of Massachusetts. All of them doing good work, and producing effluents practically beyond reproach. There is practically no odor about them. If one did not know there was a sewage farm in the district, he would never suspect its presence. Several very nice houses have been built within a couple of hundred yards of the Brockton one, and many new ones are being put up.

The cost of running these beds, outside the pumping, is not high. A couple of men are employed to keep down the weeds and to turn on the sewage. The surface of the beds are scraped over not oftener than once in three months, and it is only half an inch or so of material that needs removal. The neighboring farmers usually carry it away for manure, though its value is not very great. During the winter time the beds work as well as in summer. The only change in treatment is to ridge over the whole surface as some farmers ridge up the land in the country to cultivate turnips, beets, etc. This is usually done by a plough going up one side and down by the other, and then smoothed up with a hoe. When in cold weather the sewage is run on to the beds, filling them to the top of the ridge, it freezes on the surface, leaving plenty of space between the ridges and beneath the ice for all the sewage applied. The salts in sewage keep it from freezing solidly, and, besides, chemical action going on in the sewage keeps up a certain amount of heat. At any rate, it does not freeze under this sheet of ice. The surface, if anything, is increased for filtration. Sludge does gather to some extent, but falls to the bottom of the trenches. This is scraped up in cakes in the spring and carted away, and the ridges harrowed down level again. Sometimes the surface is ploughed over and harrowed. This improves the treating power of the beds. A study of the following figures for these Eastern towns will show what "intermittent sand filtration" will do with sewage:

City	Average gallons per acre treated	Free ammon.	Alb. ammon.	Oxygen cons.	Chlorine
Brockton, Mass.	35,500				
Raw sewage		3.01	1.36	6.44	6.59
Effluent		.1766	.0123	.13	
Framingham, Mass.	27,500				
Raw sewage		3.1012	3.145	29.46	8.45
Effluent		.6382	.0176	.18	
Lawrence, Mass. (experimental filter)	90,000				
Raw sewage		3.080	0.590	4.01	6.60
Effluent		.1113	.0207	.27	

Better than this could hardly be asked. All it requires is plenty of sandy land.

During our experiments at Berlin, Ont., we went over the hills to the east and west of the sewage farm, and dug a large number of test-holes. The land to the west, all along the ridge shows good gravel for a considerable depth, and not more than, on an average, of 15 to 18 inches below the surface. By terracing, from eighteen to twenty acres of beds could easily be made. There is one slight objection in some parts on this side. It is that about eighteen or twenty inches into the sand is a one-half inch clay stratum, which might interfere somewhat with filtration. To the east from the farm is land of a much better quality. On the very surface, the sand looks like drift sand, but after a couple of inches it is just of the quality required, and twenty-five acres could easily be made up, and at very little expense, beyond scraping off the top soil, which is here much thinner than on the west side. The greatest objection to this side is that it is closer to the town. Both sand lands are about on an equal level, some twenty feet above the sewer level at the farm. The sewage would require to be pumped to be applied to these beds, if constructed. All the Eastern cities pump, and consider themselves fortunate to have the good sand-beds at such small cost. There are no sand-beds along the valley on the same level as the sewage, or below it, within at least three miles below the farm.

With the sewage of Berlin at its present composition and quantity, nothing less than three or four hundred acres of the present clayey land would do to dispose of its sewage.

The average composition of Berlin's sewage is: Free ammonia, 2.542; albuminoid ammonia, 2.017; oxygen consumed, 49.95 per 100,000 parts.

In free ammonia Berlin's sewage is weaker than that of Brockton, Mass. Its albuminoid ammonia is one and one-half times as strong, and its other organic matter possessing the power of decomposing permanganate of potash eight times as strong. This last is not so important as the albuminoid material, though not to be neglected. It could in large part be got rid of by other methods to be mentioned presently.

Now, since Berlin's sewage, in its most objectionable feature, the albuminoid ammonia, is one and a half times as strong as that of

Brockton, Mass., and since Brockton requires one acre for each 35,000 gals., Berlin would require one and a-half acres for the same amount, and since Berlin has, on an average, 450,000 gals. a day to treat, it would take about nineteen acres of sandy land of the same character as at Brockton if raw sewage was to be treated; but auxiliary methods to be mentioned later can be introduced, which will make Berlin's sewage weaker even than Brockton's, and, in proportion, will require less land for this final process of "intermittent sand filtration."

Now, though "intermittent sand filtration" can treat raw sewage in such large quantities per acre, and is admitted to produce the best effluent of any system of sewage disposal in vogue, in certain localities it is difficult or impossible to carry out this method. The land may be too expensive, or there is no sand. It might be carried, but this by the acre at four feet of depth is expensive. Sanitarians have been on the lookout for some process that would act as an auxiliary to this method, or even replace it.

Contact Beds.—Though it has been shown that intermittent sand filtration beyond any doubt is the means at our disposal which produces the best of all effluents with sewage, there are circumstances where it is next to impossible to install such a system. Intermittent sand filtration requires a considerable area of good sand for its purpose. This is not always procurable in the neighborhood of towns. Then it may be said they can be built. Four feet deep of sand in acre beds would cost a considerable sum if this had to be carted. Then again under some circumstances, though there be sand, the land is not procurable. There are other circumstances. Perhaps it would be necessary to pump the sewage to the land. Under some circumstances this would be very expensive, not meaning by this that pumping is always expensive.

Sanitary engineers have expended a good deal of time and ingenuity to find a substitute for intermittent land filtration. The "contact bed" is the best compromise that has so far been devised. No contact bed gives the effluent that intermittent sand filtration gives, but it is better when this form cannot be used to get the next best,

and the contact bed method gives this. A contact bed is a sewage treatment bed in which the material used is placed in such a manner and is of such a character that free oxygen will gain easy and continuous access to every part of it, thus allowing the ærobic bacteria on which dependence is wholly made for the treatment of sewage to perform their function at their best. Into this the sewage is run to overflowing, with as little delay as possible consistent with non-disturbance of the material, and allowed to stand in contact with the bed's material (sometimes called filtering material, though it is not except for the very coarsest suspended substances) for a stated time. During this time the enzymes or ferments, that the bacteria have formed during their period of rest preceding this running on of the sewage, attack the organic matters and bring on oxidation, that is, introduce oxygen into the compounds, resulting in rearrangement of the molecules of which they are composed into simpler and simpler compounds, until finally only the mineral portions remain. This is precisely what is done in the intermittent sand filtration beds, only in the contact bed there is a greater supply of oxygen, more active change takes place and much more sewage can be handled. After standing this stated time, usually not more than two hours, it is gently run off so as not to disturb the bacteria that are attached to the materials of the beds in the shape of a gelatinous scummy substance, a zooglea mass as it were. If the sewage be left longer than three hours all told in contact with the bacteria these organisms are likely to be injured and may be even killed out. It is often found after a too long contact that it takes the beds sometimes even weeks again to recover their treating capacity. A contact bed is a very delicate living machine, which requires gentle, careful and skilful handling. A man may go down in a diving-bell and perform so much work. When his air supply runs out he must be brought back to the surface, if left down he dies. The ærobic bacteria during contact with sewage are in the same position, when their oxygen supply runs out they must get more. If left too long without they too die. When the bed is emptied, the surface of course becomes clear of sewage first, then farther and farther down, until the bottom is reached. This running

away of the fluid produces a void, into which the air from the surface is sucked, thus supplying it to the very bottom. And it should go there in a good contact bed. Now the bed is allowed to rest for from two to three or even four hours before the next dose is applied. Three doses to a bed in 24 hours is hard work for it. During the period of rest the bacteria live on the organic matter that is left in contact with the filter-bed material, building up more and more ferments, until at the end of the period considerable has accumulated. Now when the next dose is applied it is immediately attacked and oxidized as in the first instance.

Now though this form of bed treats a large quantity of organic material, it does not unfortunately decompose all that is run in. This is probably because a not sufficient quantity of oxygen can be got at. This is shown by the fact that after a certain period in the contact is reached no further treatment goes on. This period has been found in most cases to be reached in three hours of contact. There is nothing to gain in leaving it longer and all to lose in that our bacteria may be smothered out. Another explanation too is that possibly the products of bacterial action inhibit the function of the bacteria and even kill them. At any rate, the beds must have periods of rest. It has been attempted by mechanical means to supply a greater quantity of oxygen to contact beds to see if better results could be got. Perforated pipes have been placed horizontally at different levels in the beds and into these air is forced, in some cases previously warmed. A good deal of disturbance in the bed takes place, which probably does more harm than good in that it disturbs the bacterial scums on the bed material. At any rate it has not given what was expected. The treatment is no better, even worse in some cases, and such beds especially are found to sludge up much more rapidly than those without this artificial air supply.

The question naturally comes, how is it that these beds do not fill up or sludge up with the suspended matter going into them in such quantities? These solids are not all decomposed in this short time. And the beds do in fact sludge up, and this is one of the serious objections to them. When a bed is started, if record of its interspace

capacity be taken note of, it will be seen that for the next six weeks or two months it gradually becomes less. After this period is reached they frequently run for even years without showing any serious or appreciable diminution in capacity. The action going on is more complete than that going on in the septic tank; not so much sludge is left behind. They will nevertheless finally become filled up to such an extent that they will no longer work at all. Sometimes if a period of five or six weeks' rest be given the bed it may recover in great part its former capacity. It has accumulated probably a material that is not very putrescible. During the period of rest this becomes decomposed, and the space restored. Wood fibre and cellulose would act in this way. But if the sludging be due to mineral matter then it does not recover. The material has to be renewed or taken out and washed. This sludging up takes place much more rapidly when raw sewage is used in the bed than when the material has had some preliminary preparation such as screening, sedimentation simply, septic tank treatment, chemical coagulation or sedimentation. All these processes besides reduce the quantity of organic matter entering into the bed for treatment. The septic tank does this to the greatest extent of all. This last too is of more value still in that it primes the organic material, so that it is more easily attacked. And of course this means that the contact-bed area can be reduced. There is not so much work to do.

These beds are not filter-beds. They are simply beds in which the sewage comes in contact, under very favorable circumstances, with the active bacteria. These beds may be of various materials. Coarse or fine gravel, screened so as to remove the sand, is used.

The efficiency of a bed is calculated on its finest material. If it be sand, then the coarse material is of no use. Sand is not a good material for contact-beds. It is too fine and leaves too small interspaces for active oxidation. At Berlin, we found the best treatment to be in the bed that had the finest gravel—one-eighth inch—next the one-fourth inch, and next the half-inch. The greatest interspace capacity was in the coarser bed, of course, and, therefore, the greatest amount of sewage for treatment was in this bed. The probable

reason for the best treatment in the finest gravel bed was the fact that this bed held less sewage.

Fine broken stone, such as is used in some cities to increase friction for horses on slippery pavements, the screenings really form stone-crushers, freed from the fine material and coarser stone, such as is used for macadamizing roads, have been used. This occupies considerable space in itself, and leaves large interspaces, and does not, in consequence, supply sufficient surface. Still it has its advantages in that it is practically indestructible.

Fine broken brick is used, as also burnt ballast, and both are of about equal value. Soft coal clinkers form a good material, but are apt to crush after a time. Clinkers from all coal is not alike in hardness. Some crush easily, others are quite hard. Then comes coke. This is an ideal substance in that it is porous and is rough, and this presents more treating surface. It has another good point, viz., that when the bed is sludged up it may be taken out and burned, having lost practically none of its burning quantity or quality. Some very good hard coke is procurable from the coke ovens near Pittsburg, Penn. Some of the cokes are easily crushed, and this is a serious defect in a contact bed, leading to bad aeration and filling up of the bed capacity by sinking, etc.

Charcoal, though a good material in many ways, is so easily crushed that it is only under very exceptional circumstances advisable to use it, e.g., in small plants, where it can be taken good care of.

Coal has been recommended, also. It does not possess any special virtue, though, over many other materials, as crushed stone, for instance.

The material out of which a contact-bed is made makes very little difference in the treatment. It should be rough, but porous, not in too large pieces (half-inch in diameter at most), and of a good durable material that will not crush. It would be well to be like coke, a good material to burn when no longer useful as a treatment medium. The thing is to use what is cheapest and best at hand, consistent with efficiency.

Regarding the construction of these beds, it may be said that if the land on which the beds are to be constructed be a porous one, the beds have to be walled, and have a bottom made that will be next to water-tight at least. If the sewage can filter through the bottom, contact cannot be maintained. Some beds I saw last summer took between five and seven hours to fill. The inlets were large enough to fill them in an hour. No true contact treatment was possible here. If the land be clay, then all that is necessary is to excavate to the necessary depth, from two to four feet; a greater depth presents too great interference with proper aeration and no advantage. The bottom should be well drained with ordinary tile drains, placed in contact only, with no cement. It is well to bank the drains with coarse (three-quarter inch will do) screened gravel, free from sand. The gate controlling the outlet from these drains should be of such a kind that the flow may be checked, so that it take nearly as long to empty as it took to fill the bed, so as not to disturb the bacterial scum and attached sludge of the bed material. We must think of the head under which this emptying takes place. There is considerable pressure under four feet of fluid. Where there is much fine suspended matter in the affluent, a couple of inches of sharp sand is a good device to retain it and prevent it getting into the material proper of the bed. This sand can be removed from time to time, every month or six weeks, and more be applied. It becomes thus an additional expense, but where manufacturing sewage is being treated repays the outlay richly. It holds back fats and fine suspended material. It is to be raked over every few days, otherwise it soon sludges up.

The inlet pipe to the bed must be large enough to fill the bed in at least one hour's time. A trough distributor should be placed over the surface of the bed, so as to feed the bed evenly in all parts and at the same time, seeing at the same time again that there is not such a rush on to the surface that the bed material be disturbed or disarranged. Very few automatic arrangements for regular distribution of sewage to beds are reliable. Intelligent attendants are far more profitable, even though they cost more. The beds should be made of such a size, calculating on one hour to fill each, that there will be no hours between that sewage will have to be run off without contact,

taking into consideration the "cycle time" for each bed. The cycle for a well-run bed would be one hour to fill, two hours of undisturbed contact, one hour to empty, and from three to four hours' rest before the next dose is given, making the cycle time from seven to eight hours. Eight beds should then be constructed. Three applications in every twenty-four hours would be about as much as any bed could stand and do efficient work.

The effluents from contact-beds frequently have considerable suspended material in them. To prevent this getting into streams, it is well, under circumstances, to allow this to settle in a sedimentation reservoir of some sort, from which the effluent will overflow. This would not disturb the levels. The reservoir could be made of any depth, consistent with the easy removal of the sludge.

Contact-beds will not commence to treat sewage, except as a coarse screen, the first day sewage is run on a new bed. It takes days, sometimes even weeks, before they commence to treat, and, for the very same reasons as it takes for septic tanks to begin, viz., the selection of the bacteria, and these come from the sewage entering. Raw sewage supplies these more quickly than septic sewage does. For seeding, it is well to make the contacts for the first week or so short. The selection takes place more quickly in warm than in cool weather. Seeding with surface garden mold is said to quicken the process. The advantage of this is doubtful, when the price of it is a partial sludging of the beds, and again it is just possible that the bacteria of this earth are not inured to this special form of food material that is found in sewage.

The effluent from the ordinary contact-bed, not being up to what was required, attempts have been made to improve it by making a second contact on another similar bed, and even at some places, a third bed has been added to get a third contact. Of course, these have to be on different levels, one below the other. The effluent from bed one passes on to the surface of bed two, that from bed two on to the surface of bed three. It has been proposed to add even a fourth.

These could easily be regulated in such a way that a weak sewage would be contacted in one, a stronger in two, and so one to even the

fourth. In this way, by intelligent handling, a large treatment might be got.

The results obtained at Sutton, in England, showed that on an average 770,000 gals. of crude sewage could be treated each twenty-four hours, showing an average purification, as to albuminoid ammonia and oxygen consumed, of 64 per cent. At Manchester, England, using a preliminary septic tank treatment, 700,000 gals. of sewage per acre per day, it was found that, on an average, a purification of 75.2 per cent. of the albuminoid materials and 90.1 per cent. of the oxygen-consuming substances could be got, but this was after a double contact.

At Lawrence, Mass., in 1899, on an average, 700,000 gals. per acre per day of stale sewage was treated, with a percentage purification of 61 of the albuminoid material and 55 per cent. of the oxygen-consuming substance by the first contact, and 79 per cent. of the total albuminoid material and 75 per cent. of the oxygen-consuming substances by the second contact.

At Berlin, Ont., during the last summer's work, we were able to get on an average, 70.6 per cent. purification of the albuminoid material and 67.1 per cent. of the oxygen-consuming substances, by one contact, after using a preliminary septic treatment, running at the rate of 565,000 gals. per acre per day, leaving an effluent still containing of albuminoid ammonia .596 parts and of exygen-consuming substances 16.43 parts per 100,000, an effluent that was still putrescible.

It is hardly possible to get a complete treatment from a contact-bed. The effluent is not aesthetic, by any means. To come up to the standard of treatment required, it would need to be well diluted when passing into the final water-course. It is a compromise method. The result can hardly be compared with the effluent of an intermittent sand filter. Certainly a greater amount of sewage is handled to a given acreage, and in a given time, and certainly more organic matter is disposed of, but much more is passed through untreated also, and this is inseparable from the method. It is impossible to hold it longer in the bed for treatment, the bacteria would be killed out. The bed has to be filled at each sitting. Three or four doses can be

given a day as well as one, and one would not treat any better than if three or four were given. The bed deteriorates much more quickly than the intermittent sand filtration one, and has to be renewed. It has to be handled with a great deal of skill and discrimination. It must not be left with the sewage in contact over time. It must not be drained away too quickly, not filled too quickly. If it commences to lose its interspace capacity, this must be immediately recognized, and rest given it, or it may irretrievably be spoiled and sludged. Another disadvantage is that night men have to be used to keep the beds going. This, of course, could be got over by having a reservoir to hold all the night's sewage, treating it on the beds the next day. This would need fall, though, or pumping.

Its great application is where a not perfectly purified effluent is needed, as, for instance, where the effluent is going to be discharged into the sea or into some large water-course where a sufficient dilution can be had, and where the next town below is a long way off, i.e., far enough to give Nature time to decompose the rest.

Again, it has an advantage where sand cannot easily be got, and artificial beds have to be made. About five or six times less area is required to treat a given quantity of sewage than where sand is used for intermittent filtration. It will treat septic sewage better even than crude sewage, as the septic system has the same use with reference to these beds as to sand beds, doing half the work, only half the quantity of bed is required.

It is a compromise, too, where it would be necessary to pump a sewage to reach sand-beds, where all the handling by a contact system with a very few feet of fall could be done by gravity.

(i) *Continuous Filtration.*—This is another compromise method. It is based on Moncrieff's experiments, which consisted in placing more or less fine coke, or some such material, on shallow trays, seven inches deep, and placing these trays one above the other, with three inches of space between them, to allow of free aeration. The sewage is allowed to pass on to the upper tray, intermittent triangular tipping boxes being used, then through perforations in the tray on to the second, and so on to the third, fourth, and so on even to the last. The organic matter is found by this method to become less and less

and gradually more and more mineralized, until when it has reached the last tray no putrescible organic material is left. It shows what aeration and, consequently, oxidation, does, but it is not practicable on a large scale for sewage treatment. Several devices have been put forward to apply this principle on a working basis. The system of Prof. Stoddart has met with most favor. It is said that by this method it is possible to treat 5,000,000 gals. of crude domestic sewage each twenty-four hours on one square acre of bed four feet thick. Double the quantity is said to be treatable if the bed be made of double the above depth. Storm water does not affect its treating capacity. It will treat practically all putrescible manufacturing wastes, provided allowance is made for the quantity of organic matter that is present over and above what is the content of a domestic sewage. It has been found better to apply the sewage after a preliminary septic treatment.

The whole process depends on an uninterrupted supply of oxygen. The construction of the plant is very simple. The filtering material may be various, so long as it is coarse, hard and rough, like clinker, coke, broken brick or stone, the pieces to range in size from two to three inches, and uniform in size throughout the filter. The cheapest on the spot is best.

This is placed on a floor of concrete, with such a slope that water will not rest on it at all. There must, in consequence, be no dust or dirt in the filtering material, as this would hinder the free outflow from the bed. The sewage must be distributed continuously in a fine rain. Prof. Stoddart's distributor is constructed for this purpose. It is made of a series of narrow shallow troughs, notched at the edges to allow of overflow; at the bottom edge nails or iron points are arranged so as to break up the stream.

If it could do what is claimed for it, we should have no difficulty in treating sewage.

We experimented with a two square yard one, four feet deep, at Berlin. The material was rough clinker, well washed; the outflow was free. The distributor delivered a rather coarse stream on to the bed. It hardly came up to our expectations. The odor about it was always bad. The albuminoid ammonia and oxygen consumption was

almost not at all reduced in quantity. By Kjeldahl method the nitrogenous content was reduced. Grossly, there was a decided change. The brown color of the tannin was changed. The sewage, though, having considerable fine suspended matter in it when flowing on the bed, came away quite flocculent, the flocculi soon settling, leaving a fairly clean-looking effluent, which, though, was still putrescible. I think it would hardly be possible to run this method in our winter climate.

On the whole, we were much disappointed with the results.

No other continuous method has done better than this one. Some of the towns in England where this method has been worked with have had very little success with it. The results at Horsfield are claimed to be very satisfactory.

It has hardly proved itself one way or the other yet. It is quite possible that given time to sediment, the effluent would be good, the flocculent sediment remaining behind to undergo secondary decomposition or to be treated as sludge. We had not opportunity to determine this at Berlin.

The ideal method of treating sewage is by "Land Irrigation." Here use is made of the sewage to fertilize and to irrigate. It is expensive under our conditions in this country, and besides needs much more land than our municipalities would care to take hold of.

Intermittent Sand Filtration gives the best effluent of any method of treatment. Contact-beds are expensive, are delicate *creatures* and need too careful treatment. Experts are needed to handle them. Fifty per cent. treatment is the best we could look for. At best it is a *compromise method.* The "Continuous Filter" has not proved itself yet, but might be made useful if combined with sedimentation under conditions. The Septic Tank as an auxiliary to any of the above methods is certainly the cheapest and the easiest to run, as well as being the simplest. It will treat fifty per cent. In some cases this is sufficient, especially where sewage can be discharged into the sea. It would hardly be safe to discharge its effluent into any possible drinking water source. All these methods you will have seen depend on bacteria. They are all successful in so far as the bacteria's requirements are met.

WATER TURBINES,

W. Hamilton Munro, '04.

Within the last few years, the development of water powers in Canada, and in Ontario especially, has advanced by leaps and bounds which have a large positive acceleration.

Niagara Falls, though the greatest, is not the only spot where a development running into the tens of thousands of horse power is possible. Most of you are aware of what is being done along the Trent Canal system alone. Then think of the vast resources of the whole St. Lawrence valley, the Laurentian watershed, and the more distant regions of the west and north. Throughout these, the storehouses of Canada's timber and mineral wealth, nature has spread a dense network of rivers, small and great, which are now churning themselves to foam over precipices, roaring down wild gorges, or flowing strong and deep through silent stretches of tall timber.

Here is the foundation for the greatest electro-chemical industry in existence. Here the electrical treatment of ore can be given full scope, and under such a stimulus is bound to advance from its present infant stage to that of a fully developed science. Already the mines, and pulp and lumber mills of New Ontario are installing elaborate plants in which the song of the generator is not drowned by the puffing steam engine. To come nearer home, I consider it very far wrong to imagine ourselves in the towns and cities of Ontario paying four or five dollars a horse-power per year for power, light, heat, etc., within the next quarter century.

Thus, as future engineers, we have just cause to rejoice, if only on the score of the employment in sight; for not only does the controlling of this great asset involve the hydraulic engineer,

but it equally demands the services of the civil, to lay out and construct the dams, wheel pits and race ways; the architect to plan the buildings; and the mechanical and electrical engineer to manufacture and install the wheels and generators.

Hence it is evident that modern water power development is a question of the highest economic importance, and that it entails the best constructive ability and engineering skill of which we are capable.

The aim of the following paper is to explain the general construction and method of installation of the turbine, and to make clear its distinguishing features. No mathematics or extensive theories are introduced, and what I have to say, as a whole, will be of more interest to those knowing very little of the subject, than to any already well acquainted with it.

We will first run over the commonest devices that are now in use for harnessing the potential energy of water. With the exception of the hydraulic pressure engine, which is an apparatus closely resembling the ordinary steam engine in appearance and action, but using water under high pressure instead of steam, these devices consist of some form of wheel with vanes, the direct action of the water on the latter causing revolution of the wheel. This action is always a pressure, and it is found convenient in this connection to divide the pressures usually exerted into two classes,* viz., (1) Static Pressures, (2) Dynamic Pressures. Static pressures are those to which the sides and bottom of a tank, filled with water at rest, are subjected. Dynamic pressures are those exerted on surfaces against which a body of moving water flows. Thus if we bored a hole in the side of the tank, the static pressure would cause a jet of water to shoot out, and this jet, impinging say on the side of a block of wood, would cause a dynamic pressure over the area covered by the water probably sufficient to push the block out some distance from the tank, supposing it to be lying on a smooth surface.

* Merriman's Treatise on Hydraulics.

Water wheels may be roughly divided into three classes, which, given in order of importance, are:—

(1) Turbines.

(2) Impulse Wheels.

(3) Overshot Wheels.

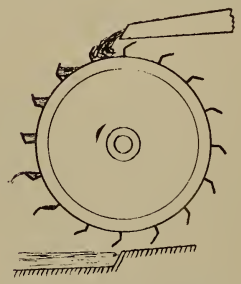


Fig. 1, Overshot

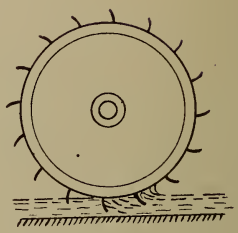


Fig. 3, Undershot

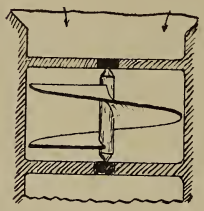


Fig. 4.

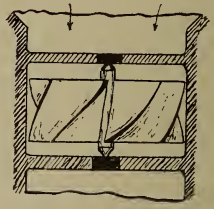


Fig. 5.

Fig. 6.

Plan

Besides these, there are great numbers of devices, practicable and fanciful, involving the same principles, but combined and applied in various and sometimes confusing ways. However, the great test of time has shown that the wheels now associated with the above names are, or were in their time in the case of overshots, the most popular.

Consider the last, first. Overshot wheels derive their power almost entirely from the dead weight of the water in their buckets pulling them around. Fig. 1 illustrates their action.

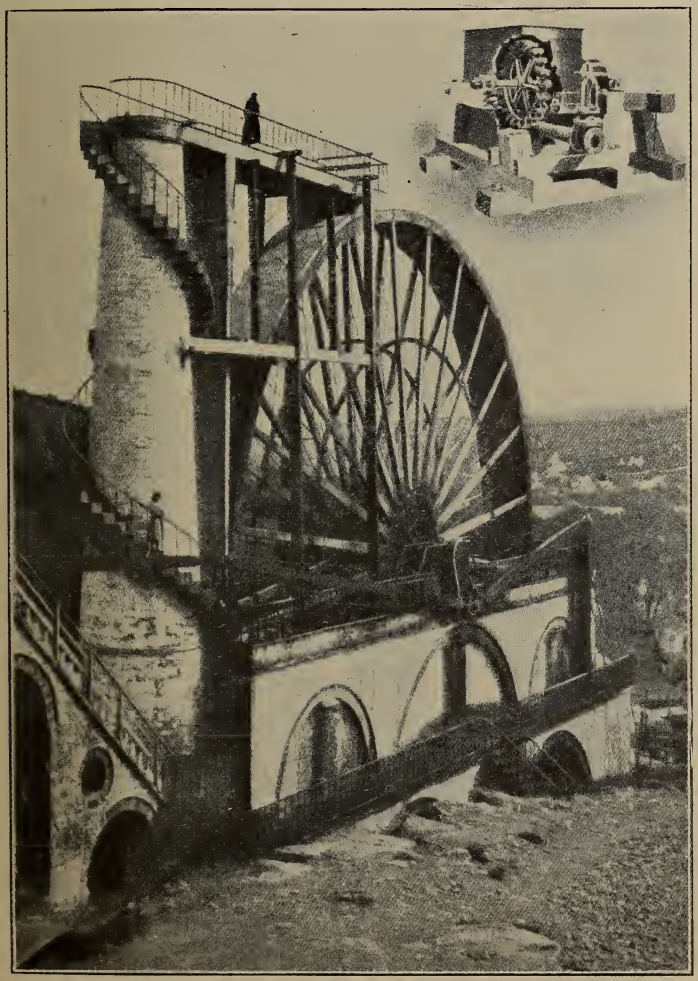


FIG. 2.—THE GREAT OVERSHOT WHEEL AT LAXEY, ISLE OF MAN, ENGLAND.
(BY PERMISSION OF PELTON WATER WHEEL CO.)

This is the form of wheel we are best acquainted with now-a-days, from picturesque illustrations on Christmas cards, etc.; though Fig. 2 shows an example of one which appears to be quite a piece

of engineering. This wheel is on the Isle of Man, it is 73 feet in diameter, and gives 150 horse power. The water is brought to it from the hills in an underground conduit, is carried up the masonry tower by its own pressure, and flows over the top into the buckets. The power is transmitted some distance by connecting rods, and is used for pumping out a mine. This ponderous machine was built forty years ago, and such has been the subsequent advancement, that the little Pelton wheel illustrated in the corner could take the old giant's place.

The Pelton is a type of "impulse" wheel. The latter is analogous to the old under-shot or current wheel, which was a large cumbersome framework, with blades on the circumference; these blades dipped into a running stream and were driven round by the dynamic pressure, or as it is popularly called, the "impact," of the current. Fig. 3 shows one in diagram. A modern impulse wheel is comparatively small. The water is supplied it by a nozzle fom which it issues at high velocity and impinges on small box-like buckets set close together on the wheel rim. In the best examples each bucket is divided into two equal parts by a partition lying in the centre plane of the wheel; the object of this partition is to split the jet, each half of the latter being then bent outward and backward on itself by the curve of the bucket, and so is shot clear and clean out of latter, on which it thus exerts a reactive effect, see Fig. 6. This disposal of the impinging water has been found to give very much better results indeed than if it were simply allowed to dash into the bucket and drop out as best it could.

Such wheels as these are well adapted for the conditions in mountainous countries, where the supply of water is small, but the head very high, sometimes, as in parts of the Rockies, 1,500 feet being used; imagine the nozzle velocity under that head. Expensive excavating and damming is not necessary for this kind of an outfit; a pipe line from a diverting dam up in the hills delivers the water directly to the wheel; the latter is usually very easily mounted by being solidly bolted to a framework of timber or a concrete base; it requires no wheel pit with accompanying penstocks, raceways, etc., and runs as well horizontally as vertically.

We now come to Class 1, viz., the Turbine, and the most important type of water motor. It may be defined as follows:—A turbine is a wheel in which the water enters around the entire circumference so that all the moving vanes are simultaneously acted upon by the dynamic pressure of the water, due to its enforced change in direction and velocity, by them.*

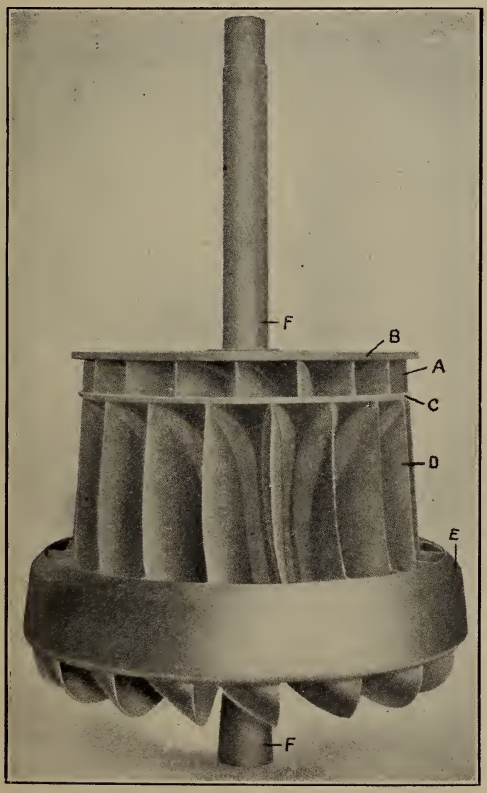


Fig. 7.

Perhaps this may be made clearer thus. Suppose we have a screw pivoted in the centre of a straight piece of pipe, whose inside circumference it just clears, referring to Fig. 4. Let the pipe be filled with water flowing downward; when the water reaches the

* Merriman.

flange, or thread of the screw, its flow is obstructed; its speed is decreased, and the directions of motion of its particles changed; to bring this about a force must have been applied to it, this force being the resistance of the screw flange to the water's passage; but action and reaction are equal, so the water exerts an equal force or pressure on the screw flange; now owing to the slope of the flange this pressure has a resolved part at right angles to the shaft, on which it therefore exerts a turning moment. The designer will of course use all possible means to make this turning moment as large as possible; for instance it is plain that the device in Fig. 5 with its many flanges and steep pitch would be the more efficient, in this case. Such is the fundamental shape and action of most turbines; in some the resemblance to a screw is quite evident, as per Fig. 7.

Turbines are divided into two large classes, viz., impulse turbines, and reaction turbines. In the former the wheel is not entirely submerged, the buckets, or as we called them above, flanges, being partly filled with water and partly with air. The reaction turbine, however, is entirely excluded from the air. Figs. 5 and 7 belong to the latter class. Reaction turbines being the more general form, we will consider them, alone.

The sub-classes under these two heads are usually based upon the direction of flow in the wheel; thus, an inward flow turbine is one in which the water enters around the outer circumference and discharges round the inner; an outward flow is just the reverse, the Niagara turbines are of this kind; an axial flow is such that the water entering at the top flows approximately parallel to the shaft and discharges at the bottom as in Figs. 4 and 5. In many makes these directions of flow are combined, increased efficiency being claimed for so doing; for example, in the runner shown in Fig. 7, the flow is inward, downward and outward, in order.

For the purpose of making the construction of a typical American turbine clear, I have chosen one particular example, and attempted to explain its arrangement and action in detail, and when necessary made comparisons with other wheels.

Take the "Samson" Leffel turbine, which is made by the Wm. Hamilton Mfg. Co. of Peterboro', for this country. This wheel is the result of over forty years' experience, is kept thoroughly up to date, and is probably as efficient a power transformer as there is in this line. Its general lay out and appearance are shown by Figs. 7, 8, and 9.

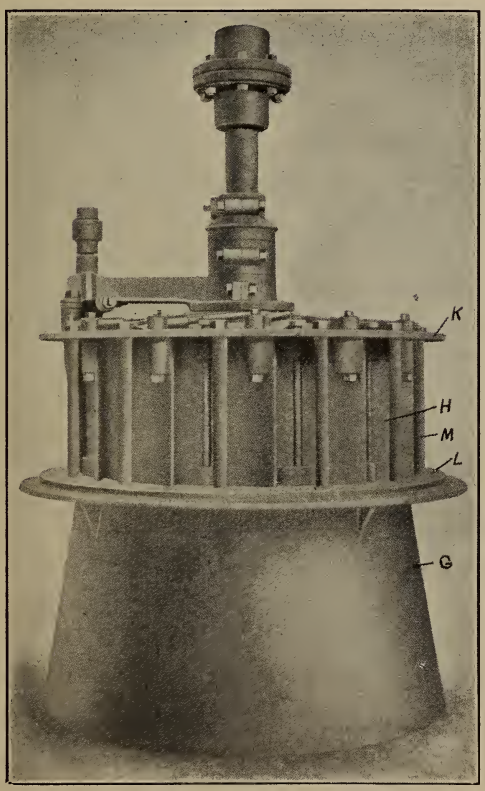


Fig. 8.

Beginning with Figs. 7 and 9 we will examine the vital part of the whole machine, viz., the runner. As you observe, it really consists of two distinct wheels. The buckets of the upper one A, which is an inward flow, are cast iron and of one piece with the hub B and the centre cone-shaped diaphragm C. Into this

diaphragm the inside edge of each large bucket D is imbedded; the lower outside edge being gripped by a heavy cast iron ring E. The double wheel design gives a runner for which is claimed greater strength, finer balance, larger capacity, higher speed, and more satisfactory efficiency than one having a single set of buckets. The large vanes are of steel plate, and are made thus:—

The shape of each when developed—that is, laid out flat—is marked on the plate and sheared out, the piece is then heated to redness and hammered into the proper curved shape over a metal form, on which it is held by clamps at the corners, or by a press; finally, holes are drilled along the edges, which will be imbedded in the frame, in order to give the cast iron a good hold; the blades are stocked and used as required.

When a runner is to be cast, a set of buckets for the required size is brought out and accurately fitted to a template, in the machine shop; this template also acts as a pattern for the diaphragm, so the buckets are left on it till they are solidly rammed up in the sand of the mould; by this arrangement absolute precision of spacing, inclination, etc., is ensured for them. Other runners are made entirely of cast iron, in one piece, and it is sometimes claimed that in wheels of the former type the buckets will loosen and the outside ring crack; with good workmanship, however, this is practically impossible, and I have yet to see or even hear of such a case in connection with the Samson. A solid one-piece runner is clearly a very difficult casting to make, and besides the trouble of setting the cores true, it is just as liable to strains and cracks as the separate bucket form, probably more so.

Where a turbine is to be used under a very high head, a cast iron wheel of reasonable proportions is found unable to withstand the stress due to increased pressure and higher velocities; for this reason special runners of a tougher metal, say brass or bronze, have to be employed. Owing to their extensive experience with such cases the Swiss and Italian makers are at present the most expert designers and builders of high head turbines, and there are many examples of their work on this continent, where

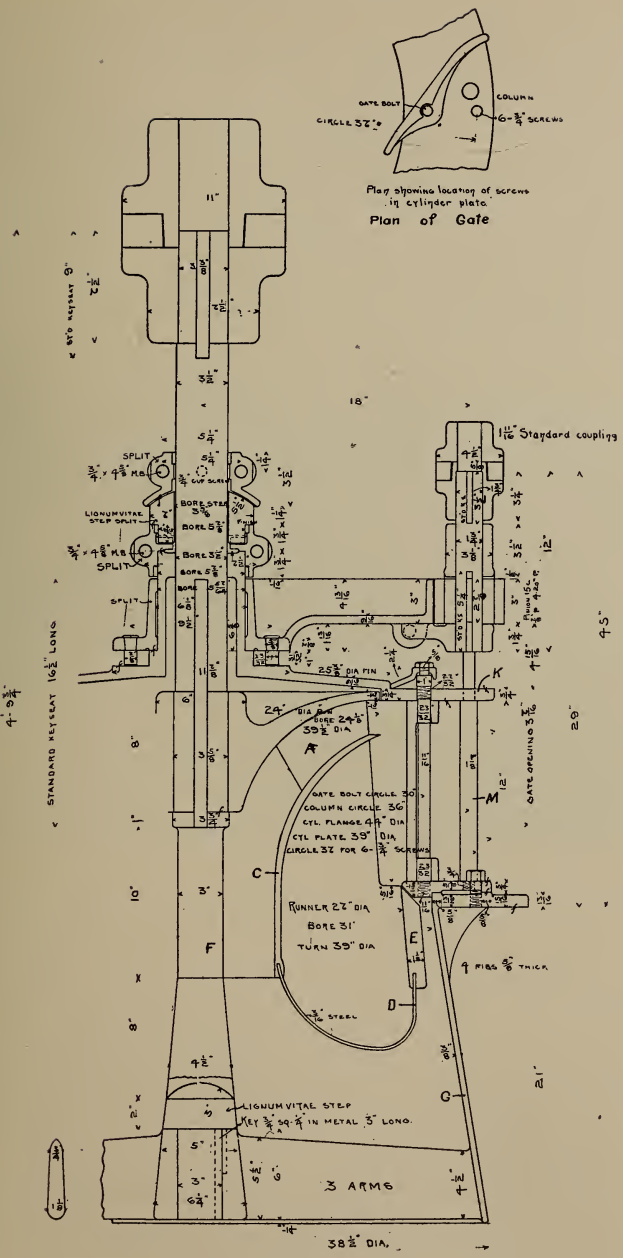

GATE BOLT
COLUMN
CIRCLE 32"ø
6-¾" SCREWS
Plan showing location of screws in cylinder plate
Plan of Gate
1 1/16" Standard coupling
SPLIT
LIGNUMVITAE STEP SPLIT
STANDARD KEYSEAT 16½" LONG
25⅝" DIA PIN
24" DIA
BORE 24⅛"
39½" DIA
GATE BOLT CIRCLE 36"
COLUMN CIRCLE 36"
CYL. FLANGE 41" DIA
CYL PLATE 39" DIA
CIRCLE 32" FOR 6-¾" SCREWS
RUNNER 22" DIA
BORE 31"
TURN 39" DIA
4 RIBS ⅝" THICK
GATE OPENING 29"
LIGNUM VITAE STEP
KEY ¾"sq-4" IN METAL 3" LONG.
3 ARMS
38½" DIA.

FIG. 9.

they have been called in to help out the American hydraulic engineer, who is more accustomed to large volumes and low heads.

Comparatively little machine work is necessary on the runner we are considering. In addition to boring out the shaft hole, and cutting key ways (two for large sizes), the only other work is beveling the top, and rounding off the bottom of the lower outside ring, and turning the outside rim of the hub, true. The runner is balanced like an ordinary flywheel, but by chipping off weight rather than adding it; its vanes and all channels in which the water flows are gone over with a chisel and scraper, and any unevenness removed and the whole given several coats of smooth water-proof paint; a rough runner wastes power in water friction. If the turbine is of the upright style illustrated, the runner is fitted with a short piece of special shafting F. It is apparent that in the upright style the whole weight of the runner and the downward thrust of the water must be taken up by collars and an end bearing. The end bearing on a turbine is usually quite simple and of the following form: The lower end of the shaft is flared and a saucer-like hollow turned and polished in its face; a block of lignum vitæ, a hard, oily, tropical wood, is rounded off to fit this hollow exactly, the grain of the wood being parallel to the axis of the shaft so that the greater the weight the closer is the wood compacted; the block is supported by a spider J, from the walls of the draft tube, Fig. 9. Such a bearing is very durable indeed; it is lubricated by the water and requires no attention whatever.

Now, the runner is of course the vital part of every turbine, and upon its design depends, almost entirely, the value of the efficiency of the machine. Hence a large number of experimental and mathematical formulas have been prepared on various occasions by manufacturers and scientists, giving the best arrangement, curvature, angles of approach and discharge, etc., for the buckets, and these formulas must of course be discreetly applied in designing or improving any particular turbine. However, for our purpose here, the sum and substance of the designer's formulas may be concisely stated in the two following practical rules which must be observed if high efficiency is desired.

(1) The water must enter and pass through the turbine without losing energy in friction and foam.

(2) The water must reach the tail race level with its velocity as nearly as possible reduced to zero.

Let us now turn our attention to the draft tube G, and the casing H, Fig. 8. The use of the draft tube is to dip below the tail water and lower the discharge from the wheel into the raceway, see Fig. 11. In general, the shorter the drop, S, from runner to tail water, the better; but it is evident that within a certain limit the

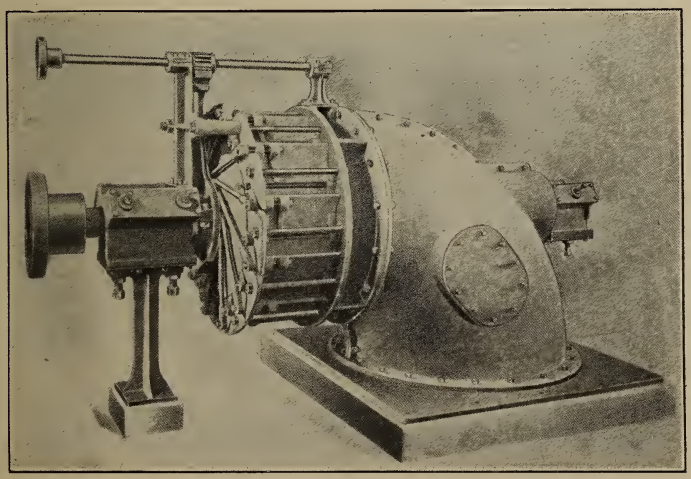


FIG. 10.—SINGLE HORIZONTAL SHAFT TURBINE FOR OPEN PENSTOCK.

runner may be placed above the tail water, the action then being as follows: Since air is entirely excluded from the turbine by the water above and around it, hence the tail water rises in the draft tube and is supported by the atmosphere in the same way as the mercury in a barometer; this rise does not mean a loss of head, because it is exactly counter-balanced by the atmospheric pressure on the head water, but the whole phenomenon simply allows us some latitude in fixing the level of the runner between the head and tail waters. If the vacuum were perfect, the artificial tail water level in the draft tube would stand 34 feet (height of water barometer) above the real level, and hence the runner could be given the same

elevation. However, such a state of affairs would be quite impossible to either obtain or maintain in practice, the maximum usually being about 20 feet, and even these heights are used only when special circumstances, such as high heads, position of machinery, etc., demand them.

In all cases the draft tube must be made long enough to be always below the tail water level, otherwise the column of water inside will immediately drop out and a head corresponding to S, Fig. 11, be lost, in fact the proper operation of the turbine would be altogether spoiled. A slight expansion toward the bottom is an improvement in the draft tube.

From the discussion above you can see that the paradox of a turbine mounted and running above the head water level is quite within the range of possibility, and in fact has been found to work successfully. .

Now, the water must be brought up to the buckets and delivered in a way calculated to have the most effect on them; also means must be provided for controlling the supply. Hence the runner requires a casing provided with water guides and gates.

The standard form of casing for the Samson is constructed as follows:—A cast iron plate K, called the dome, and having a hole for the shaft to pass through in the centre, is bolted to a broad, flat ring, L, by heavy wrought iron columns, M, around the edge; shoulders on these columns keep the dome and ring a fixed distance apart. The ring rests on the top flange of the draft tube, and its inside edge is bevelled to correspond to the top of the outside ring of the runner which fits close up to it.

In this type, "balanced" or "wicket" gates are used. They consist of cast iron plates in plan like an elongated S, Fig. 9. They are placed upright and overlapping between the dome and the ring, and pivoted by rods up their centres through lugs provided, thus they open and close very much in the same way as the slats of a window shutter. The dome, ring, and top and bottom of gates are of course, machined, so that a practically water-tight fit is made. For easy turning, a shim under the centre of each gate raises it

about 1-64 inch so that it will not rub on the ring. These shims are of the best Swedish iron.

With regard to the method of handling the gates, refer to Fig. 10. From the outer upper corner of each gate a bolt projects through a curved slot in the dome plate and is fastened to a slider above, a rod is run from the slider to a collar which turns about a shoulder in the centre of the dome, each rod is secured to the edge of the collar by a pin through a hole in its end; thus, when the collar is given an eighth of a turn or so, it draws in the outside ends of the rods and hence swings the gates together; a reverse turn opens

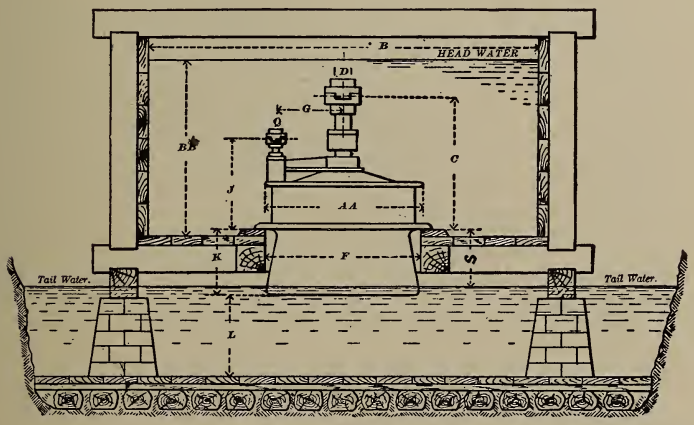


FIG. 11.—DIAGRAM OF TURBINE MOUNTED IN OPEN PENSTOCK.

them. The collar is operated by an arm which projects from it and carries a rack, the latter engaging a pinion on the gate shaft leading to the governor as seen in the figure.

Two great advantages of this gate are the following:—It is easily operated under all heads, for no matter what the pressure, the force tending to close the gate and that tending to open it balance each other, one on either side of the centre pivot. Secondly, it combines the property of a gate and a guide by giving the water the proper direction against the vanes, when open.

There are two other styles of gate in general use, but each requires a separate set of guides built on the wheel casing.

The first is what is called the cylinder gate. It consists simply of a hollow cylinder, like a big piece of pipe, which slips up or down around the runner; when it is down the water is shut off.

The second is the "register" gate. It requires a casing the side of which is divided alternately into open and closed panels, a hollow cylinder fits closely inside of this, and it also has corresponding open and closed panels in its wall; the gates are opened by turning the inside cylinder until two open spaces coincide, on the sliding door principle.

Usually a turbine is arranged to run normally and give its maximum efficiency at about seven-eighths gate, that is with seven-eighths its full supply of water entering; this allows a good margin for governing under ordinary conditions.

Finally, in the design of any gate the following important points must be kept in mind. First, the gates should be in hydraulic and mechanical balance, i.e., the only force to be overcome in moving them being the friction of bearings. Secondly, there should be no lost motion in the gate-moving mechanism. These two conditions are in the interests of the governing apparatus. Lastly, the gates should change the water supply without materially affecting the efficiency.

So much for the construction of the turbine; now as to the methods of putting it in working position.

The first thing to do in developing any fall or rapid, is to accurately determine, (1) the head, (2) the volume of water available per minute, (3) the steadiness of the supply.

The head is the vertical distance between the level surface of the water in the upper reach and that of the lower reach, called respectively the head water and the tail water. Fig. 1. The head can be accurately determined by an engineer's level, if the drop is great or conditions such as long rapids, etc., prevent direct measurement.

The second quantity, the discharge, is gotten best in either of two ways, the one used depending on the size of the stream. For large streams, the area of the cross-section as estimated by taking the depth at regular intervals in it, and plotting, is multiplied by the

average velocity of the current, the latter being obtained from the observation of floats well submerged, or from a current meter.

Information as to the steadiness of the supply, i.e., whether or not the stream is subject to floods and dry spells, can only be obtained from a study of its sources and its behavior at various seasons of the year as reported by those acquainted with it.

From the head and discharge, and other conditions such as speed required, and kind of machinery to be driven, the number and size of

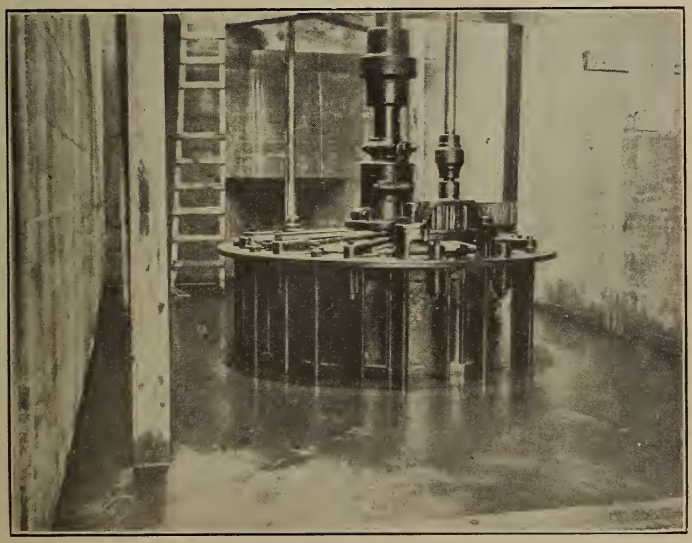


FIG. 12.—A 68-INCH SAMSON TURBINE READY FOR BUSINESS.

the turbines necessary, for any development, can be figured. It is best to leave this and the design of the installation to the firm supplying the wheels.

Next as to the actual installation. A very common method is the following. First the river is dammed, about a third of the whole length of the dam consisting of a great box, A, Fig. 13. The upstream side of this box is open, and the bottom extends over the tail

race at about the same level as the latter. It is divided into compartments (penstocks) by piers running up and down stream, and in the centre of each penstock a round hole is left in the floor; into this hole the turbine is placed resting on the flange of its draft tube so that in its efforts to flow down into the tail race the water must pass through the turbine. Fig. 11 shows an upright wheel in a wooden penstock or flume. The wood is merely for illustration, in all first-class modern plants the construction is entirely of steel and concrete. The penstock floor should be especially strong and rigid so as to support solidly the busy wheel and the mass of water about it. By the way, before entering the penstock the water is strained through the rack to clear it of driftwood; the rack is a sieve made by bolting iron slats face to face, each being separated two inches or so from the next by washers on the bolts, and the whole supported on a frame work of beams, across the forebay. Refer to Fig. 14.

When laying out raceways, flumes and pits always keep the following condition in mind as of vital importance, viz.—Have unimpeded supply and discharge for the wheels. That is, make the entrances to the forebay and penstocks of such dimensions that the velocity of entering water will never exceed two feet per second, otherwise when the wheels are running at full load the level of the water in the penstocks will drop for lack of supply; in many cases the lost power resulting would be fatal. Similarly, the tail race must be so broad and deep that the water never backs up on itself in the least, but flows slowly and smoothly away. The following rule if adopted will avoid trouble on this score. There should be one square foot of cross-section in flume and tail race for every hundred and ten cubic feet of water used per minute, and the clearance under the draft tube should vary from two to ten feet according to the size of the wheel.

Fig. 13 shows in diagram two common methods of mounting in open penstocks, and the consequent placing of generators. The first case is that in which upright turbines are employed. A wheel is set in the penstock, as shown in Fig. 11, and its shaft run up to the top of the dam, where by a pair of bevel gears *a,a,* it transmits its

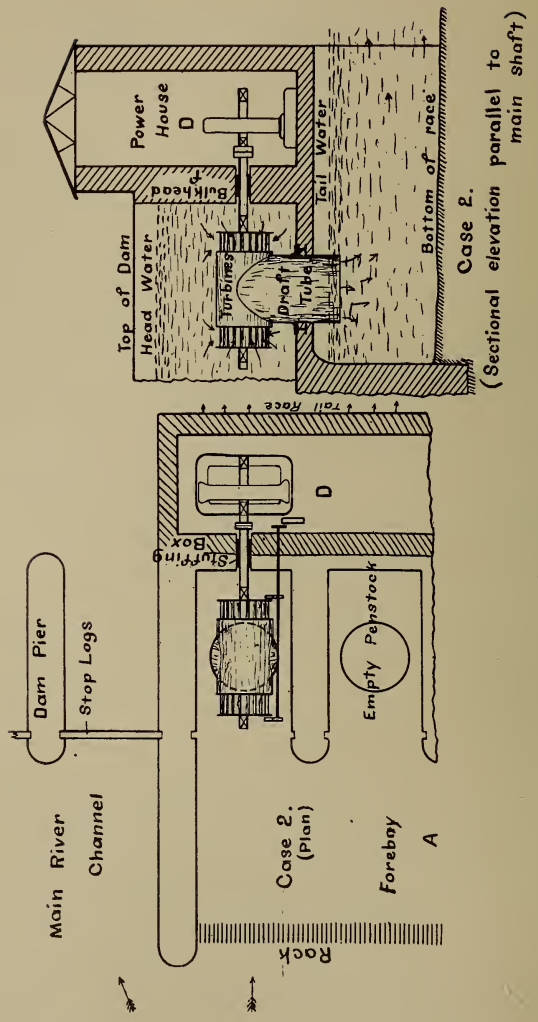
power to a horizontal or lay shaft, *b*, coupled to the generator C, in the power house on the river bank. Nearly always there are several turbines in a row, all driving the same lay shaft, when only every alternate wheel turns in the same direction, so as to do away with any end thrust on the shaft due to the gears, and to equalize things throughout. The gears *aa* are made large and heavy, the under one usually being a mortise wheel with teeth of paraffined maple; each set is borne by one, or for heavy duty two, bridgetrees bolted to a box girder construction built of I beams and which is bedded in the concrete piers on each side. A good solid, rigid outfit is necessary to overcome vibration and give easy smooth running. The lay shaft is in sections, getting heavier as the power transmitted becomes greater, and is well supplied with heavy ring-oiling bearings; the gates are also operated from a horizontal shaft to which the upright rods are severally geared and the whole connected to the governor.

Besides the vertical there are half a dozen styles of horizontal mounting for turbines, the particular one used depending on the conditions of head, kind of work to be done, and extent of the power unit.

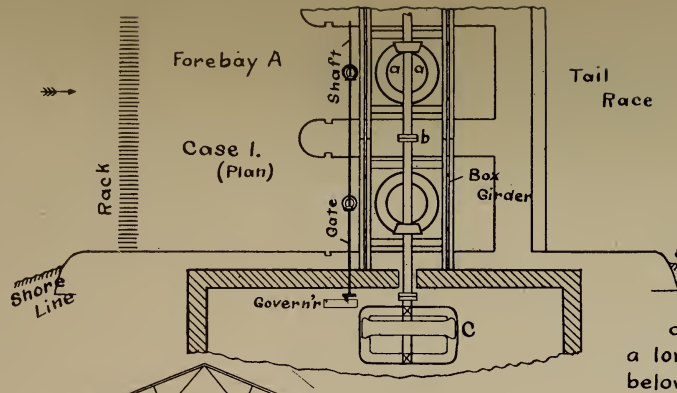
By horizontal mounting, we mean that the runner shaft is horizontal. The great advantage of such an arrangement is that the wheel may be put on the same shaft as the dynamo, rotary pump, pulp grinder, or whatever it happens to be driving, and hence elaborate gearing is dispensed with.

In whatever position the turbine is running, whether vertical, horizontal or sloping, and it makes no difference which as far as efficiency goes, the runner is always the same, changes being made only in the draft tube, in the bearings, and sometimes in the method of handling the gates, depending on circumstances.

Thus, Fig. 10 shows a single horizontal turbine as mounted in an open penstock. You see its draft tube is given a quarter turn. The shaft runs straight through, and it and the gate rod are extended through stuffing boxes in the back wall of the penstock, into the power house, whose floor is on the same level as the penstock floor.



PART OF FIG. 13.



General construction material. Concrete backed with steel beams and expanded metal.

The tail race is often run some distance parallel to the river, behind a long pier, so as to utilize any drop below the dam.

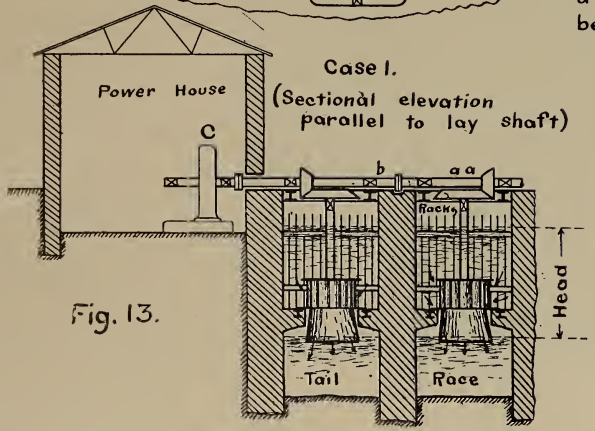


Fig. 13.

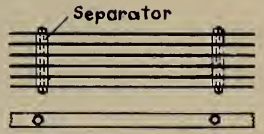


Fig. 14.
Showing how rack is put together.

From the quarter turn, an extension of the tube drops to below the tail water as in the upright type draft tube. The wheel as shown is, of course, submerged when the penstock is filled, for which reason the bearings are not babbit lined, but a special form is used which allows the shaft to run on blocks of lignum vitæ; as iron screws would rust, the blocks are kept in place by set screws of brass. The water acts as a lubricant, and in some forms of bearings is forced into them under pressure through pipes from a pump in the power house.

This is the style of wheel which is used in case 2, Fig. 13, only that in the figure each shaft carries two wheels, one right hand in

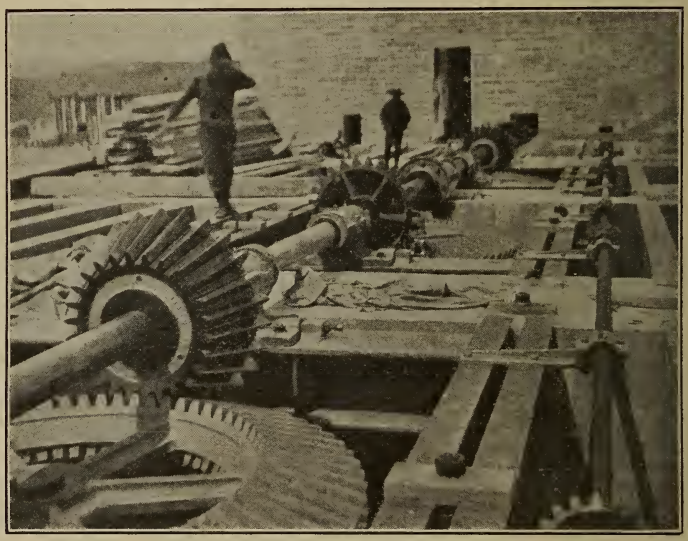


FIG. 15.—SHOWING THE BOX GIRDER CONSTRUCTION SUPPORTING THE GEARS, ALSO GATE SHAFT, BEARINGS, ETC.

rotation, the other left, and discharging into a common draft tube; the arrangement is made clear by Fig. 16. You see the power house D is on the same level as the penstock, and is built right over the tail race; the shaft *b* and the gate rod are carried into the house by stuffing boxes in the bulkhead *f*.

Remember that horizontal mountings need to be especially well supported, because any loss of alignment in a direct connected outfit

is much more troublesome than if sets of gearing intervene to take it up.

Quite often, instead of using open penstocks, the casing of the turbine is surrounded by an outer casing of steel plate rivetted up like a large tank and well clear of the turbine. From the steel penstock a pipe leads to the head water reservoir, and the arrangements for discharge are exactly the same as before, see Fig. 17.

Outfits of this kind are designed to meet the following circumstances:—High heads and large power, as at Niagara, when the ordinary method by damming is out of the question; at the Falls the

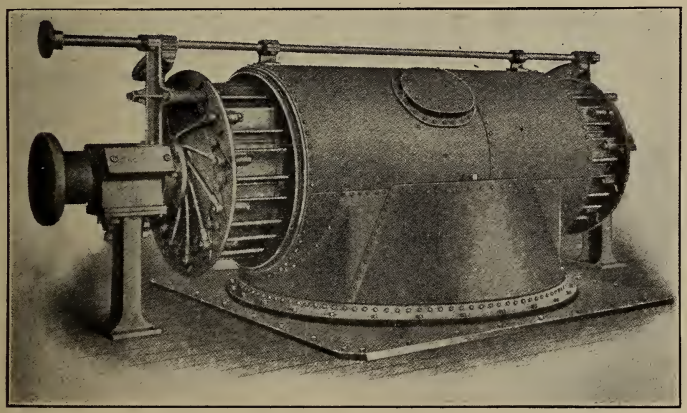


FIG. 16.—TWIN CENTER DISCHARGE, HORIZONTAL SHAFT TURBINES FOR OPEN PENSTOCK.

scheme is to run a canal or conduit from the upper river and from it feed long steel penstocks which drop one hundred and thirty feet or so over the edge of the gorge or into specially excavated pits; the wheels are at the bottom of these tubes and discharge into a tunnel leading into the lower river. Secondly, when economy of space is required, for the encased wheels may be set up right in the house beside the machinery to be driven. Also thirdly, water may often be led in piping from places which are quite inaccessible otherwise, for example say the head of a cataract in a mountain torrent where there is no natural means of confining the water with the aid of a dam.

Care must be taken to see that the intakes of the flumes are never allowed to take air and that all joints are tight. Above all there is the destructive action of "water hammer" to be counteracted in all cases where the flume is of any length.

Suppose you have a pipe supplying a turbine running at nearly full gate, and for some reason the load suddenly decreases and the governor partially shuts off the water supply, the velocity in the flume is at once decreased and the impetus of the long column runs the pressure up to such a point that if it is not relieved the flume will quite probably burst like a gun. This danger is usually avoided by such means as the following. A relief valve, resembling closely a boiler safety valve, is put on the penstock or just in front of the gate valve; if one is used take care to have it large enough. The shock may also be taken up on a cushion of air by putting a good sized chamber on the pipe and keeping it full of air. Lastly, when the head is not too high, a stand pipe no doubt makes the best safety device and is also a good pressure equalizer.

As to regulation, there are several types of efficient and extremely ingenious water wheel governors now on the market, and the problem has already been ably put before you in previous papers, but I might say that it well deserves earnest study from those, especially, who are interested in hydraulic-electrical engineering. Fig. 17 shows a governor attachment to the gate rod.

In conclusion, let me mention a matter which is of primary importance in the efficient operation of almost every plant, and that is the systematic conservation of the surplus water present at certain seasons of the year in the area drained by the power-giving stream, and the regulation of this surplus so as to equalize the discharge from the basin.

The general method of such a system is by storage in tributary lakes and marshes; dams are built across the outlets and these natural reservoirs allowed to fill above the usual levels, then in seasons of drought the stop logs are gradually lifted and the supply kept up to the demand down stream, until the time of plenty returns.

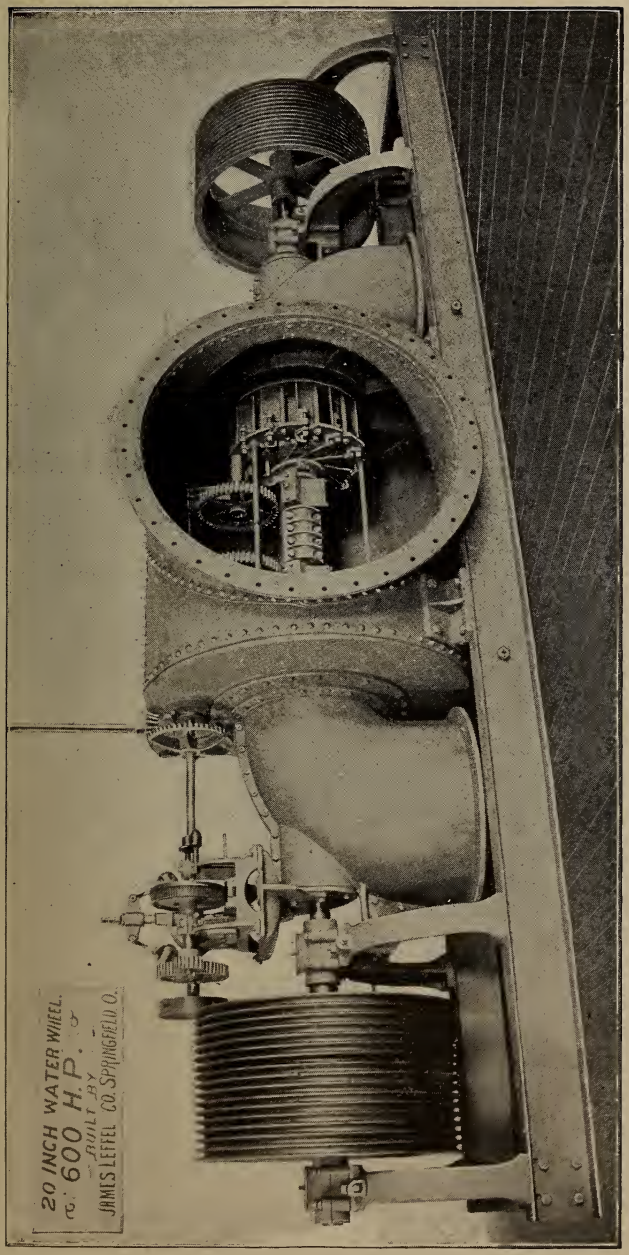


FIG. 17.—PAIR OF TURBINES IN A STEEL PENSTOCK, DIRECT CONNECTED TO ROPE PULLEYS

Take for example the Trent Valley system here in Central Ontario. So far, little has been done in this regard outside the regular canal route, despite several petitions to the government from the lumbering, navigation, and power companies of the district. The result is that every spring, and after protracted wet spells to a lesser extent, every little rill magnifies itself fourfold, the lakes rise and disgorge themselves into the main rivers, which then roar high over the spillways and shutes, carrying battering rams of uprooted trees and masses of ice to tear out the banks, smash piers and bridges, and cause general alarm and destruction. Then in the dry months comes the reaction, steamers plough the mud and tear out their bottoms on granite rocks, gangs of river men cant and pole their logs over miles of exasperating puddles just deep enough to bump them from one boulder to the next, and all the while the heads on the turbines creep down and down, with spasmodic revivals due to an occasional heavy rain storm.

Now scattered over this whole region are myriads of beaver meadows, ponds, and lakes linked by short streams to one another and to the main channel; these, by a judicious placing of dams could be made to hold over practically all the spring freshet, so providing an abundant supply of clear water throughout the summer and fall for every town from Midland to Trenton. Of course it requires time to build up such a system, but if gone about determinedly after well laid out plans, and a dam put in or a ditch cut here and there every year, its good effects would speedily become apparent while the resulting saving of power, protection of property, and other minor benefits would amply justify the expense.

SEWAGE DISPOSAL.

WILLIS CHIPMAN, B.A.Sc., O.L.S., M. CAN. SOC. C.E., M. AM. SOC. C.E., M. AM. WATER WORKS ASSOC.

The proper disposal of the wastes from a large town or city is frequently a most difficult problem to solve, one demanding the professional skill and experience of the most eminent sanitary engineers.

The principles involved are now supposed to be well understood, but it would perhaps be safer to say that they are now better understood than formerly.

During the latter half of the nineteenth century, the chemistry of sewage was carefully studied, and many processes of sewage purification were brought out. Some of these had merit, others none. The chemicals added to the sewage, as a general rule, simply accelerated the precipitation of the suspended matters and retarded putrefaction. They were settling and pickling processes. The disposal of the sludge produced involved the construction of large tanks and buildings, the installation of more or less complicated machinery, all of which appealed to the generous ratepayers, but as a rule the maintenance charges proved burdensome, and the results were far from satisfactory.

In Ontario we have a good example of chemical works at Hamilton, and those of you who are interested might spend there a few days very profitably.

Several smaller chemical works in the province have been abandoned in whole or in part, or have been remodelled to adapt them to the bacterial process.

In the United States the works at Worcester, Mass., Columbus, O., Providence, R.I., and several other places, might be inspected with profit.

It was early discovered that chemistry alone could not solve the problem entirely. Several tons of semi-liquid sludge produced from each million of gallons of sewage had to be disposed of. Owing to the quantity of mineral matter it contained, not only the minerals in the crude sewage but those added in the precipitation process, it was found to have little value as a manure.

To convert it into a fertilizer by adding it to other well known fertilizers, thus adulterating them, was expensive, although still followed in several places as a means of getting rid of it.

In large seaport towns, the most economical way of disposing of it has been to convey it to sea by means of tank steamers.

To dry it in the open air, took a long time, and putrefaction setting up, most offensive odors were produced. Drying it mechanically by filter presses was also an expensive method, but the most satisfactory, and this is the one now in general use. The cakes produced are as a rule burned or given away to market gardeners.

The effluent from chemical works, although it may be comparatively clear, contains in solution such quantities of putrescible matter that further purification is generally desirable.

From time immemorial it has been known that human excreta could be disposed of by applying it to land, being as a rule covered, dug into, or mixed with surface soil.

Raw sewage, either with or without sedimentation, applied in moderate doses to land, will become purified in passing slowly through the soil, but the land must be suitable, the area sufficient, and the management must be intelligent to ensure success.

Within recent years the science of bacteriology has arisen, revolutionizing many theories, explaining many enigmas.

By the aid of bacteriology, the theory of the purification of sewage by land treatment became better understood. Experiments carried on independently by engineers, bacteriologists and others under

instructions from Government authorities, demonstrated that air and bacteria were essential to purification, and that the character of the materials through which the sewage passed was not so important.

Owing to the density of the population, the large number of manufactories, the small volume of the streams, and the necessity for protecting public water supplies, England has led the world in municipal work for purifying water and sewage.

In 1892, Mr. W. J. Dibdin, then Chemist to the London County Council, constructed at the Barking outfall of the main sewerage works of London, on the north side of the Thames, an experimental bed, about one acre in superficial area, the filling material being three feet of fine coke. After some failures he was enabled to remove 35 per cent. of the impurities from sewage, when applied at the enormous rate of 800,000 gallons per 24 hours.

Further experiments demonstrated that by using coarse materials in the bed and increasing the depth, 50 per cent. of the dissolved putrescible and oxidizable matter could be removed from over 1,500,000 gallons per day. These results astonished sanitarians throughout the world.

In 1896 Mr. D. Cameron, City Engineer of Exeter, constructed there the first septic tank system, of which we have all now heard so often.

In this system the crude sewage flows continuously but very slowly through a large tank, in passing through which about 60 per cent. of the putrescible matter is removed by bacteria.

The working bacteria in the septic tank are known as anærobic, as they require no air for their existence, while those in the beds are called ærobic.

The effluent from a septic tank is frequently more offensive than crude sewage, the solids having been broken up in the tank, but it is in proper condition for further purification on land or beds.

Whether the septic tank process be adopted or beds, additional treatment is necessary, if it be desired to remove more than 50 per cent. to 70 per cent. Enlarging the tank or passing the sewage through additional tanks will not effect this, but application to land

or treatment on another set of beds will effect as high as 90 per cent. purification.

The first cost of a septic tank with all appurtenances is practically the same as that of a bacteria bed of the same capacity and efficiency, but the former has the advantage in operating expenses, as it requires but little attention, while the surface of the beds must be frequently raked and at intervals renewed.

The application of the sewage in rotation to the beds may be done by an attendant or by automatic apparatus operated by the sewage itself.

In large works where a number of laborers are necessary night and day, the filling and emptying of the beds may be done by hand, but in small cities and towns this would be a large item of expense.

Several devices have been patented for automatically filling and emptying the beds, allowing each bed in rotation (*a*) to be slowly filled, (*b*) to stand full any desired length of time, (*c*) to be emptied slowly, (*d*) to stand empty for æration and desired time.

This is a field in which mechanical engineers should exercise their ingenuity. He who succeeds in perfecting a simple automatic apparatus that will work satisfactorily in this climate, will merit a substantial reward. The apparatus must be so designed that any one or more beds may be cut out without disarranging the system, and the length of times for filling, for standing full, for discharging and for æration must be such, that they can be regulated at will. The apparatus must also be reasonable in first cost, simple in construction, positive in action, and durable.

In Great Britain the continuous application of sewage to deep beds of coarse materials has given excellent results. The sewage is distributed by revolving sprinklers, by tipping troughs, by notched or perforated channels, by overflowing over the sides of V-shaped troughs, and dropping from points below, etc., etc., the principle being about the same in all. In this climate, however, the beds would have to be housed to ensure operating in cold weather.

For Government Institutes, hospitals, summer hotels, sanitariums, etc., where sufficient fall can be secured, this system will probably prove satisfactory, and cheaper than any other now known.

Bacteria beds dosed intermittently are called contact beds. If crude sewage be applied to them, they will gradually silt up with suspended matter. The best results are obtained by first passing the sewage through septic tanks. Roughing filters of coarse materials have also been adopted in some places, but septic tanks are more satisfactory. Coke and cinders both rough and porous, are the best filling materials for the beds.

In beds to which the sewage is continuously applied, broken stones, coarse gravel. hard coal, etc., have proven satisfactory. In these beds the accumulations of suspended matters tend to fall off from the materials of the bed and pass out with the effluent.

In Canada, several cities and towns have constructed so-called septic tanks or bacteria beds or both.

At Berlin, a septic tank of insufficient capacity was constructed a few years ago to treat the sewage before passing it over land which had become waterlogged from over doses of sewage, but the tank was altogether too small for the work. Stratford has had a similar experience.

At London, two bacteria beds out of four proposed, were constructed in 1902, but during the coal famine of last winter, the coke in the beds was removed by the authorities and used as fuel in the different city buildings. Ultimately four additional beds will be constructed at London and probably a septic tank.

At Guelph, two concrete septic tanks were constructed last year, and during the coming summer beds will be added. When completed the Guelph disposal works will probably be the most interesting in the province.

Where purification of sewage is essential, storm water should be rigidly excluded from the sewers, that is, the strictly separate system should be adopted, and if the water supply be metered to consumers, the cost of operating the sewage disposal works will be materially lessened.

Sewage purification has not been discussed seriously by many cities or towns in this province. The courts have in some few instances imposed penalties for damages to mill owners and riparian owners along streams polluted by sewage, and in other places municipal authorities have been enjoined to abate the nuisances created, but in general the law has been evaded.

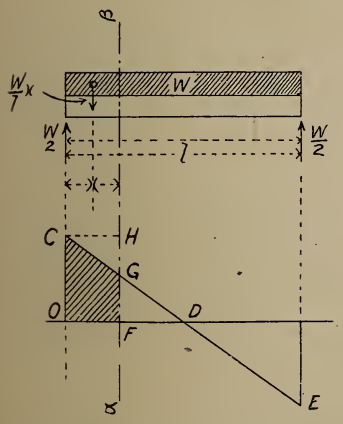
As a rule the ratepayers of a town in Ontario will vote almost unanimously in favor of a by-law to bonus a railway or a proposed factory; on a water works by-law the vote is generally favorable, and on a sewer by-law doubtful. For sewage disposal only the Engineer's estimates are pared down to the last dollar, the money is grudgingly voted, generally under compulsion; and after the works are completed they are supposed to do what was expected of them automatically. It is more difficult to secure an appropriation of $1,000 per year for sewer maintenance, or for operating sewage purification works, than to obtain the assent of the ratepayers to $100,000 bonus, representing five times the annual taxation.

From the foregoing it is evident that the pathway of the Sanitary Engineer, who presumes to design sewage disposal works, is not a happy one. His reputation may be more or less impaired through the ignorance and parsimony of the municipal authorities who employ him.

A FEW POINTS IN GRAPHIC STATICS.

C. H. C. Wright, B.A.Sc., Professor of Architecture.

The Area of the Shearing Force Diagram Represents the Bending Moment.



Let the annexed diagram represent a beam supporting a uniformly distributed load W. The vertical shearing force at any plane $a\ \beta$ is the algebraic sum of the forces to the left of the plane, i.e.:

$$V.S.F. = + \frac{W}{2} - \frac{W}{l}x$$

When $x = O$, $V.S.F. = \frac{W}{2}$, and $V.S.F. = O$ when $x = \frac{l}{2}$ hence the ordinate to the straight line $C\ D\ E$ at any plane $a\ \beta$ represents the $V.S.F.$ at that plane. Now the bending moment at the plane $a\ \beta$ is the algebraic sum of the moment of the force to the left of the plane about any point in the plane, i. e.: $B\ M = + \frac{W}{2} \cdot x - \frac{W}{l}\, x \,.\, \frac{x}{2}$.

But in the $V.S.F.$ diagram, $O\ C$ and $C\ H$ represent $\frac{W}{2}$ and x respectively, therefore $\frac{W}{2}\ x$ may be represented to the area of the rectangle $O\ C\ H\ F$.

Again because $F\ G$ represents the $V.S.F.$ at $a\ \beta$ it represents the difference between $\frac{W}{2}$ and $\frac{W}{l}\ x$ and as $F\ H$ represents $\frac{W}{2}$ therefore $H\ G$ represents $\frac{W}{l}\ x$.

Hence $\frac{W}{l}\, x \,.\, \frac{x}{2}$ may be represented by $H\ G \,.\, \frac{C\ H}{2}$, i. e., by the area of the triangle $C\ H\ G$.

But $B.\ M. = + \frac{W}{2}\, x - \frac{W}{l}\, x \,.\, \frac{x}{2}$ and may be represented by area of the rectangle $O\ H$ less the area of the triangle $C\ H\ G$, or the area of the figure $O\ C\ G\ F$.

Hence the bending moment at any plane $a\,\beta$ is represented by the area of the *V. S. F.* diagram to the left of the plane.

The Fink Roof Truss

Let the annexed diagram, Fig. 1, represent a Fink roof truss supporting the loads $A\,B$, $B\,C$, $C\,D$, $D\,E$, etc., and let the reaction of the left wall be $M\,A$.

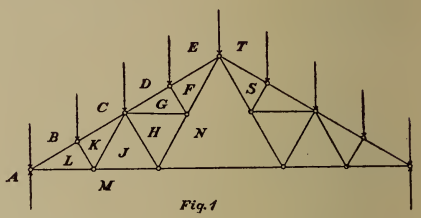


Fig. 1

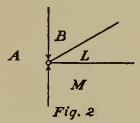


Fig. 2

Consider first the forces acting on the point $A\,B\,L\,M$. There are two known forces $M\,A$ and $A\,B$ and two unknown $B\,L$ and $M\,L$ exerted by the members $B\,L$ and $M\,L$ on the point as in Fig. 2.

From any point M., Fig. 3, draw the lines $M\,A$ and $A\,B$ to represent the wall reaction $M\,A$ and the load $A\,B$. Through B and M draw the lines $B\,L$ and $M\,L$ parallel to the directions of the forces $B\,L$ and $M\,L$. Let these lines intersect at L. Then $M\,A\,B\,L\,M$ is the vector diagram for the point, and the lengths of $B\,L$ and $L\,M$ represent the magnitudes of the forces $B\,L$ and $L\,M$ acting on the point. The force $B\,L$ being a push and $L\,M$ a pull, hence the member $B\,L$ is in compression and $L\,M$ in tension.

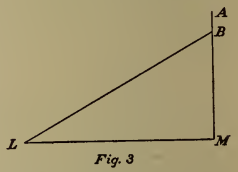


Fig. 3

Proceeding to the point $B\,C\,K\,L$ the known forces acting are $L\,B$ and $B\,C$ and the unknown $C\,K$ and $K\,L$ as in Fig. 4.

Fig. 4

From any point L, Fig. 5, draw the line $L\,B$ parallel to the force $L\,B$ and from it cut off the length $L\,B$ to represent the magnitude of the force, and from B draw $B\,C$ to represent the force $B\,C$.

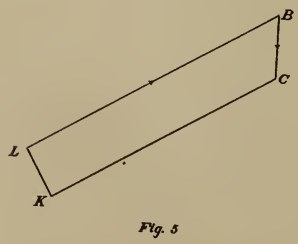


Fig. 5

Through C draw $C\,K$ parallel to the force $C\,K$ and through L draw $L\,K$ parallel to the force $L\,K$ intersecting $C\,K$ in the point K.

Then $L\,B\,C\,K\,L$ is the vector diagram for the point, and $C\,K$ and $K\,L$ represent the forces $C\,K$ and $K\,L$. These are both pushes on the point, and therefore the members $C\,K$ and $K\,L$ are both in compression.

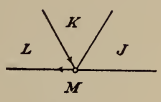


Fig. 6

Considering the forces acting on the point $J\,K\,L\,M$ there are two known forces $M\,L$ and $L\,K$ and two unknown $K\,J$ and $J\,M$ as in Fig. 6.

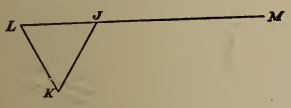


Fig. 7

The vector diagram being $M\,L\,K\,G\,M$, Fig. 7, where $K\,J$ and $J\,M$ represent the forces $K\,J$ and $J\,M$. As they are both pulls on the point the members $K\,J$ and $J\,M$ are in tension.

Now examine the conditions existing at the point $D\,E\,F\,G$. There is one known force $D\,E$ and three unknown, $E\,F$, $E\,G$ and $G\,D$, as indicated in Fig. 8.

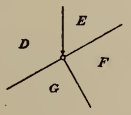


Fig. 8

Fig. 9

Fig. 10

Two of these forces $D\,G$ and $E\,F$ act in the same direction and will have a resultant acting in this same direction. Substitute for these two forces their resultant R, making the set acting on the point $D\,E, G\,F$ & R, Fig. 9.

Draw the vector diagram, Fig. 10, for these three forces. The lines $D\,E$, $G\,F$ and R will represent the forces $D\,E$, $G\,F$ and R, and as $G\,F$ is a push on the point the member $G\,F$ is in compression.

At the point $F\,G\,H\,N$ there are four forces acting, one of which $F\,G$ is known and the others $F\,N$, $N\,H$ and $H\,G$ are unknown and act as in Fig. 11.

Fig. 11

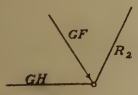


Fig. 12

Of the unknown forces $F\,N$ and $N\,H$ act in the same direction and will have a resultant acting in that direction. Substituting this resultant for the two forces the set of force becomes $G\,F$, $G\,H$, R_2, (Resultant of $F\,N$ and $N\,H$), Fig. 12.

Draw the vector diagram $G\,F$. $G\,H$, R_2, Fig. 13, and the length of the line $G\,H$ gives the magnitude of the tension in the member $G\,H$.

Fig. 13

Combine these four vector diagrams in one, Fig. 14.

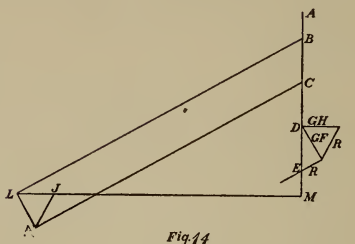


Fig. 14

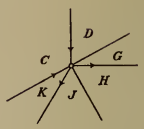


Fig. 15

The diagram. Fig. 15, represents the condition existing at the point *C D G H J K*. There are two unknown forces *D G* and *H J*.

Draw the vector diagram *J K C D, G H, D G, H J*, Fig. 16, and the length of *D G* and *H J* will give the magnitude of the unknown forces.

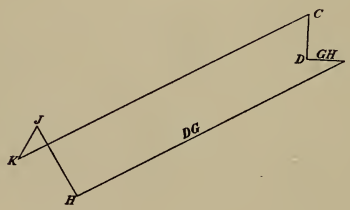


Fig. 16

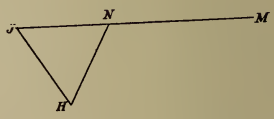


Fig. 17

The vector diagrams for the points *M J H N*, *N H G F* and *D E F G* are given in Figs. 17, 18 and 19 respectively.

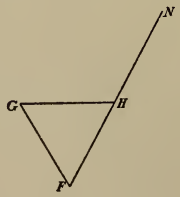


Fig. 18

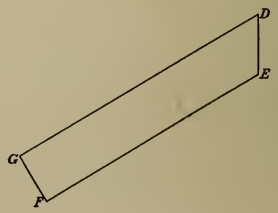


Fig. 19

Adding these four vector diagrams to Fig. 14 completes the combined diagram as in Fig. 20.

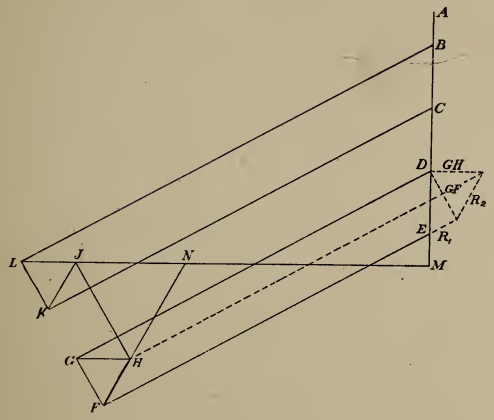


Fig. 20

Suppose the loads $A\,B$, $B\,C$, $C\,D$, $D\,E$ and $E\,F$ are unequal, that their total is equal to the load on the right hand principle and that the lengths of the members BL, $C\,K$, $D\,G$ and $E\,F$ are unequal as in Fig. 21. Proceed as in the above problem and construct the vector diagram, Fig. 22.

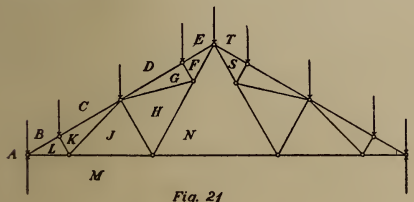


Fig. 21

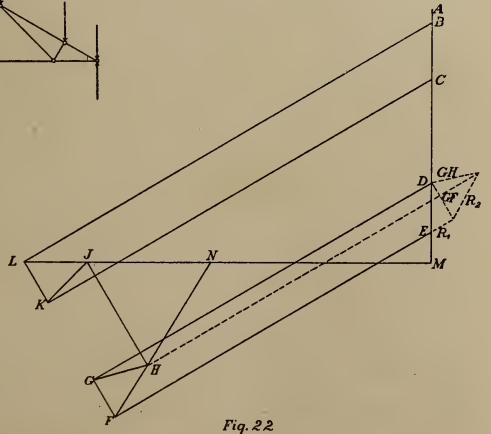
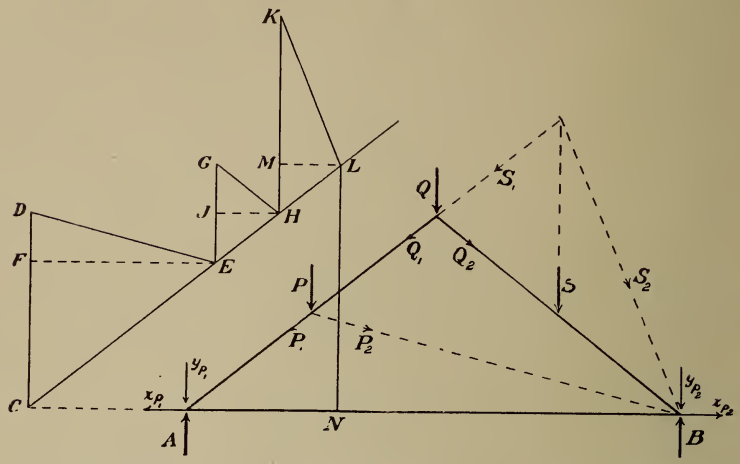


Fig. 22

Graphical Determination of Wall Reaction.



Let the annexed diagram represent a roof truss acted on by the three loads, P, Q and S.

Each of these forces may be replaced by its components in any two directions such as P_1 and P_2. for P, Q_1 and Q_2 for Q and S_1 and S_2 for S as indicated in the diagram.

From any point C in the horizontal line BA produced draw CD to represent the force P. Through C and D draw the lines DE and CE parallel to the components P_1 and P_2. DE and EC will represent these components P_1 and P_2 respectively.

Again the component P_1 may be replaced by its horizontal and vertical resolved parts X_{P_1} and Y_{P_1} acting at A. Similarly P_2 may be replaced by its horizontal and vertical resolved parts X_{P_2} and Y_{P_2}. From E draw EF perpendicular to DC then

EF will represent the horizontal resolved part of P_1 i.e. X_{P_1}.
FE " " " " P_2 i.e. X_{P_2}.
FC " " vertical " P_1 i.e. Y_{P_1}.
DF " " " " P_2 i.e. Y_{P_2}.

As the horizontal resolved parts of P_1 and P_2 are equal in magnitude, act in the same direction and of opposite sense their resultant is O and they may be neglected. Thus the original force P is replaced by Y_{P_1} acting at A and Y_{P_2} acting at B.

From E draw $E.G.$ to represent Q and through E and G draw $E\,H$ and $G\,H$ parallel to the components of Q, i.e. Q_1 and Q_2.

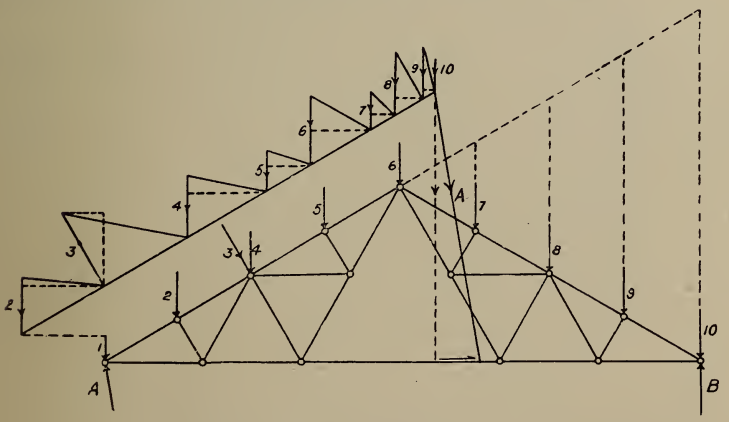
From H draw $H\,J$ perpendicular to $G\,E$, then $J\,E$ and $G\,J$ represent Y_{Q_1} and Y_{Q_2} respectively.

Similarly draw $H\,K$ to represent S and $H\,L$ and $K\,L$ parallel to the components of S, viz., S_1 and S_2. Then $K\,H$ and $K\,M$ will represent Y_{S_1} and Y_{S_2}.

The original forces P, Q and S may be replaced by the vertical resolved parts $Y_{P^1} + Y_{Q_1} + Y_{S_1}$ acting at A and $Y_{P_2} + Y_{Q_2} + Y_{S_2}$ acting at B.

But Y_{P_1}, Y_{Q_1} and Y_{S_1} are represented by the lines $F\,C$, $J\,E$ and M respectively, therefore their resultant will be represented by the length of the line $L\,N$.

The wall reaction at A must be equal and opposite to this resultant and will be represented by the line $N\,L$.



Suppose the adjoining Fink Roof Truss to be fixed to the wall A, on roller bearings at B, and supporting the loads 1, 2, 3, 4, etc., as indicated. In this case the vertical resolved part of the wall reaction A would be determined as before, and the horizontal resolved part would be the horizontal component of force 3.

SCHOOL OF PRACTICAL SCIENCE CHEMISTRY AND MINING BUILDING.

The view on the opposite page will give our readers some idea of the new "School of Practical Science Chemistry and Mining Building" at its present stage of construction. The observer's station is south-westward, at the corner of College Street and University Crescent.

The building is intended to accommodate the departments of Applied Chemistry (including Electro-chemistry), Mining, Metallurgy, Mineralogy and Geology, and comprises lecture-rooms, laboratories and rooms for collections to illustrate the instructions in these subjects. The administrative offices of the School of Practical Science will also be situated in the building, as well as the quarters of the Professors and Instructors in the above subjects. At the rear is a separate building for a very complete and modern milling and ore-dressing plant. The power and heating plant, in a wing also at the rear, will supply heat, ventilation, light and power to the new building, and light and power to the old building north of it.

THE SURVEY OF DOMINION LANDS.

F. D. Henderson, '03.

The charter of the Hudson's Bay Company, under which for two hundred years it had exercised sovereign authority over Rupert's Land, expired in 1870; and owing to the efforts of the Federal Government, exerted through its representatives Sir George Cartier and Hon. Wm. McDougall, on the Home Government, the vast tract of land stretching from Hudson's Bay to the Rocky Mountains, and from the 49th parallel of latitude to the Arctic Ocean, and containing not less than a million square miles, became part of the Dominion of Canada.

The Company's revenue was derived from the fur trade with the Indians; and it is not surprising that not only was little or nothing done to civilize them, but that the incoming of white settlers was discouraged. In two hundred years only one settlement of importance had grown up. This was in the neighborhood of Fort Garry, the Company's post near the junction of the Red and Assiniboine Rivers, and was known as the Red River Settlement. The first surveys in all the North-West were made by Messrs. Sabine and Goulet to fix the boundaries of some river lots granted by the Company to these settlers.

In the summer of 1869, some months before the Canadian Government was to assume formal possession, Lieut.-Col. J. S. Dennis, Provincial Land Surveyor, was sent westward with instructions to devise and report upon a system of survey which would render some lands almost immediately available for settlement, and would at the same time be capable of being extended over the whole North-West.

Col. Dennis recommended that the country be divided into square townships containing 64 blocks or sections of 800 acres each, exclusive

of road allowances. These were to be numbered northward from the international boundary and to lie in ranges numbering east and west from a principal meridian drawn from some convenient point on the boundary.

This method of basing a survey on an initial point, through which are drawn a meridian and a parallel of latitude, was not original with Col. Dennis, but had probably been devised by General Putnam, an American officer in the Revolutionary war, and first used in 1786-7 in the State of Ohio. Since then it has been extended to all the Western States. The chief point of difference in the scheme recommended by Dennis was in the size of the townships, which in the United States contain 36 blocks of 640 acres each.

Col. Dennis seems to have assumed that his scheme would be adopted, for no sooner had he sent his report off to Ottawa from Fort Garry than he took the field and proceeded to lay down the first initial meridian, or Winnipeg meridian, beginning at a point near the international boundary about ten miles west of Pembina. He ran this northward for sixty or seventy miles, and then laid out some townships in the neighborhood of what is now Oak Point, Manitoba. Meanwhile his recommendations had been adopted by Order-in-Council of September 23rd, 1869. But the "high-handed and undiplomatic conduct" which marked his dealing with the settlers precipitated the Red River Rebellion of 1870, and all surveying operations were suspended for the time.

Before they could be resumed the Lieutenant-Governor of the newly-formed Province of Manitoba, Sir Adams Archibald, made recommendations to the Secretary of State to the effect that the system of survey be altered, "retaining the rectangular principle but making the townships six miles square with road allowances on all township and section lines of 1.50 chains wide." This was adopted, and on May 1st, 1871, the first Manual of Surveys was issued, containing instructions to the Deputy-Surveyors, as they were then called, for carrying on the work.

On March 7th, 1871, Col. Dennis was appointed Surveyor-General of Dominion Lands, and about the same time the administration of

the work was transferred from the Department of Public Works to that of the Secretary of State, a branch called the "Dominion Lands Branch" being created. In 1873 this branch was transferred to the Department of the Interior, where it has since remained. It is now called "The Topographical Surveys Branch."

In 1878 Col. Dennis was succeeded by Mr. Lindsay Russell, who held the position until 1884, when he retired on account of ill-health, and Capt. E. Deville, the present Surveyor-General, who had been Chief Inspector of Surveys, assumed office in March, 1885.

Since 1871 the work of dividing up our great North-West has gone steadily on. Some idea of the immensity of the task may be gathered from the fact that in 1883, when the C. P. R. had crossed the fertile belt and a large influx of population was expected, the Government sent out 119 surveyors, who ran about 70,000 miles of line, and whose labors threw open for settlement over 26,000,000 acres of land. It is probable that this record of a single season's work has not been equalled in the history of the world.

BASE LINES.

Under the system initiated in 1871 the townships were laid out of an exact width of 480 chains, exclusive of road allowances, on certain lines called "Base Lines," which were run from the principal meridian every twenty-four miles. The 49th parallel of latitude, or International Boundary, thus became the first base. The second base is between townships 4 and 5; the third between townships 8 and 9, and so on.

These base lines are an approximation to parallels of latitude and require to be run with great care. They are not continuous lines, but consist of a succession of chords about six miles long, each chord being the line in which a great circle drawn at right angles to the meridian passing through the center of the township, cuts the surface of the earth.

At the 49th parallel the angle by which the line must be deflected at a township corner in order to keep in the same latitude is 6′ 03″; at township 20 it is 6′ 26″.1; at township 40, 6′ 51″, and at township

60, 7′ 18″. Through these deflection points on the base lines meridians are run 12 miles north and 12 miles south, and these form the east and west outlines of the townships.

CORRECTION LINES.

Owing to the convergence of these meridians the two townships lying to the south of a base line increase in width, while the two to the north decrease. The line on which allowance is made for this "jog" is called a "Correction Line." The first correction line lies between townships 2 and 3; the second between townships 6 and 7, and so on. On the first correction line the "jog" is 3,422 chains at the west side of range 1; 6,844 chains at the west of range 2, etc. The amount of jog increases in the townships to the north, so that on the 18th correction line it is 4,238 chains west of range 1; 8,476 chains west of range 2, and so on.

INITIAL MERIDIANS.

It follows that the townships of any given range get gradually farther and farther west as we go north, and this condition is more marked in ranges lying far from the initial meridian. To prevent any material difference in longitude between townships in the same range, as well as to get rid of the errors that are sure to appear in field work, especially when done under conditions existing in the early days, it was determined to run a second initial meridian from which the ranges might begin again to number westward. The Winnipeg meridian was found to be in west longitude 97° 27′ 09″. The second meridian, as it is called, was established in 1875 by triangulation from the principal meridian, and is in west longitude 102°. Subsequently a third, fourth, etc., have been added, each being four degrees west of the preceding one.

To fix the location of any township it is only necessary to give (1) the number of the township; (2) the number of range; (3) the meridian; and (4), in the case of the principal meridian, to state whether the range is east or west. For example, the 4th township from the 49th parallel in the 12th range west of the second meridian

is described as Township 4, Range 12, west of the 2nd mer.; or briefly "Tp. 4 - 12 - 2." The 3rd township from the 49th parallel in the 5th range east of the principal meridian is Tp. 3; R. 5; E. of Pr.; or briefly, "Tp. 3 – 5 - E."

FIVE SYSTEMS.

The general principles on which the survey was based in the beginning have always been adhered to; but changes have been introduced from time to time, either on the score of economy, or to make the system simpler, or to render it suitable to local conditions. In this way there are now *five* systems.

All five are alike in this, that each township contains 36 sections which number from the south-east corner westward and eastward alternately, across the township. so that section 36 is at the north-east corner. The section is a block of land measuring about one mile each way. It is divided into quarter sections of approximately 160 acres. Also in all the systems the surveyed lines are run and posted on the south and west sides only of the road allowance (if there be a road allowance); except in the case of correction lines and the boundaries of Indian reserves. In both of these lines are run and posted on both sides of the road allowance.

FIRST SYSTEM.

In the first system the road allowances are 1.50 chains wide, and are left between all sections, i.e., to subdivide the township into sections, five lines are run north and south and five east and west. This makes a township 489 chains square. The lines running north and south are made parallel to the east boundary of the township; the excess or deficiency due to divergence or convergence of meridian outlines is allowed for in the west tier of quarter sections.

SECOND SYSTEM.

The second system differs from the first only in having the lines that run north and south true meridians, i.e., the chords at the north and south of the township are divided into six equal parts, and lines are run to join the points of division.

THIRD SYSTEM.

The third system has been in use since 1881, and covers all the North-West except the comparatively small area in Manitoba and the districts adjoining it to the west, that are included in the first and second systems. The road allowances are one chain wide, and only two lines are run from east to west, instead of five, as in the first and second systems. It is estimated that this omission of eighteen miles of line in each township means a saving to the Government of between two and three million dollars.

The township measures, theoretically, 486 chains east and west, and 483 chains north and south.

FOURTH SYSTEM.

The fourth system is in use in a belt of land twenty miles wide on each side of the Canadian Pacific Railway in British Columbia. In general it is the same as the third system; but instead of leaving a strip one chain wide along the section lines, an allowance of three acres for roads is added to each quarter-section, which thus becomes theoretically 40 chains 50 links from east to west, and 40 chains 25 links from north to south. When the township is settled the road may then be located in the most suitable place.

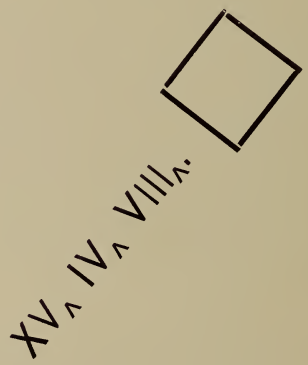
FIFTH SYSTEM.

The fifth system includes some townships within the railway belt in British Columbia, which were surveyed by the Provincial Government previous to the transfer of the lands to the Dominion. The basis of the system is the 49th parallel of latitude, and a meridian called the Coast Meridian, passing near the junction of the Fraser and Pitt rivers. The townships are exactly six miles square, have no road allowances, are given individual numbers, and lie on both sides of the coast meridian. No allowance is made for convergence.

MONUMENTS.

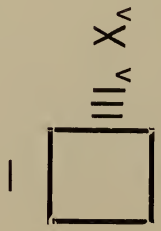
As the whole object of the surveys is to establish certain points on the ground from which the boundaries of the parcels of land can

be determined, the marking of these points in a permanent way becomes a matter of the greatest importance. In all work done in recent years an iron post is placed at each section corner, and four pits of regulation size are dug around it. In bush the earth from these is piled up in the form of a square pyramid, and the official name for such a monument is "Iron Post and Mound" (I.P.M.). In prairie the earth is scattered around, and the monument is "Iron Post and Pits" (I.P.P.). The iron post is a piece of $\frac{3}{4}$" gas pipe three feet long. One end is plugged and pointed, and the other plugged and made square for about six inches from the top. On this the surveyor marks with a cold chisel the section, township, and range. Thus,



is the marking on the post at the N.E. corner, Sec. 15, in Tp. 4, Range 8. The marked side faces the south-west.

Posts on correction lines have the number of the section on the west side and the township and range on the north or south side. Thus,



is the marking for the post at the south-east corner of township 3, range 10. Posts at township corners are 5′ long and $1\frac{3}{8}$″ in diameter.

Quarter section corners on the line have wooden posts with pits, or pits and mound, as at the section corners. If there is no bush within three miles, the surveyor is allowed to mark the quarter section corner by pits only.

WITNESS MONUMENTS.

In case a section corner falls in a slough, pond, or stream, the iron post is planted at a some convenient point on the line, an even number of chains back from the true corner. A trench is dug around it; and, if in bush, a mound is thrown up. The post is marked to indicate the direction of the true corner and its distance from the post.

For example, if an iron post and trench is planted four chains south of a certain section corner the post is marked "4 N." and the official name of such a monument is "Witness. Iron Post and Trench." (Wit. I.P.T.)

DAY-MEN AND CONTRACTORS.

At first all surveys of Dominion lands were made under contract. The surveyor contracted with the Government to do a certain amount of surveying at so much per mile, and out of this he paid all his own expenses. It soon became apparent that this arrangement was more advantageous to the men who did the sub-dividing, as they had not so much expense in moving camp; and also that the men who ran the meridians and base lines (the part of the work requiring the greatest care) were apt to do careless work in their efforts to economize.

Accordingly, since 1874 there have been two classes of surveyors, familiarly known as "day-men" and "contractors," according to the manner in which they are paid. Of course a "day-man" of this year may be a "contractor" next year. and vice versa. At present the day-man receives $6.50 per day ($7.50 per day for services requiring special qualifications), and practically all expenses for himself and party.

The contractor's rate of pay depends on the kind of country through which he runs. For running the line he is paid $5 per mile; for bush up to 10 chains in a section line he is paid 50 cents a chain; for bush over 10 chains in a section line, 25 cents per chain; for a corner monument in prairie, $1, and in bush $1.60.

A further payment of $3 per mile is allowed for rough or hilly ground. Five dollars is allowed for an observation, if properly recorded, but not more than two observations are paid for in each township. Rivers and large streams and lakes of more than twenty acres must be traversed, and for this he is paid $11 per mile.

These are the rates as fixed in the last edition of the Manual issued April 2nd, 1903, and they cover the cost of making the survey and preparing an office copy of the field notes. The surveyor is no longer required to plot his notes. That is now done in the office of the Surveyor-General at Ottawa.

BLAST FURNACE GAS ENGINES.

H. H. Angus, '03.

During the last few years, furnace-charging appliances, with double closing arrangements, have been adopted with the object of reducing to a minimum the loss of gas, by forming, above the cone proper, where the charge is piled up, veritable sacs or cells in order that the gases on being introduced into the furnace shall not escape. Among the best known European appliances for double closing is the Lewis, which consists of a cone and a charging hopper covered by a closing plate; and in this plate there are apertures, closed by flap valves when the cone is lowered, while at that moment a weight, intimately connected with the lower cone, rests on levers which bring about the closing. A well known American appliance invented by Mr. Julian Kennedy, consists of two bells one above the other. The charge is placed in the hopper of the first bell, which is then opened, and the charge falls on the second bell. As soon as the first, *i.e.*, the upper bell, is closed, the second one is opened and the charge falls into the furnace. Cowper stoves are now given a diameter of about 23 ft. and a height of 90 ft., this new arrangement permitting of sufficiently heating the outer air before it mingles with the gases. Moreover, thanks to the Lürmann and other burners, the combustion takes place under better conditions. Lastly, blowing engines are now designed to supply a larger quantity of air at higher pressures with a minimum expenditure of steam.

Side by side with these improvements, and depending on them to a great extent, has come into use the blast-furnace gas engine. Steam now becomes unnecessary for motive power and thus costly and even dangerous steam boilers are not required. A great saving

in gas is effected and the latter may therefore be utilized for subsidiary services.

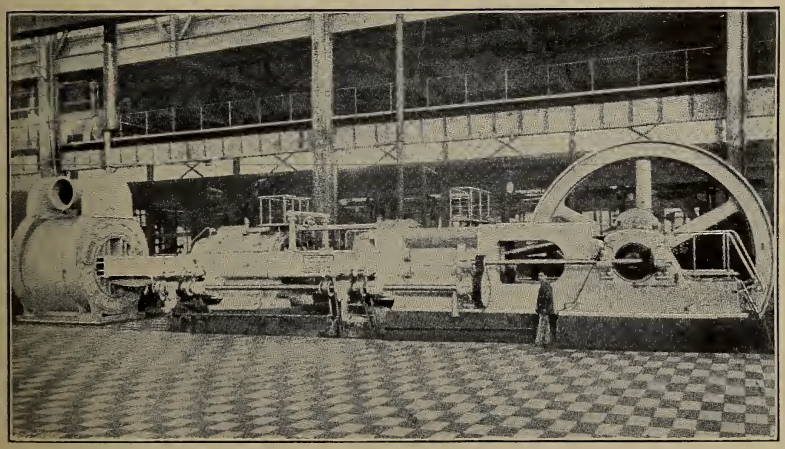
In dealing with the question of blast furnace gas engines, the first subject to be considered is the production and quantity of the gas. When the coke, ore and flux pass slowly down the blast furnace shaft there rises a very rapid gaseous current engendered by the combination of the air blown in at the tuyeres with the incandescent carbon, which therefore consists at first of CO_2 and N, but soon afterwards of CO and N. These two currents meet and exchange their calories, there being a reduction of the ore with the decomposition of the flux and consequently transformation of CO into CO_2 (thus $Fe_2 O_3 + 3 CO = 2 Fe + 3 CO_2$), on the one hand, and the disengagement of CO_2 on the other. At the same time another re-action, discovered by Sir Lowthian Bell, occurs near the furnace mouth due to contact of the gas with the sub-oxides of iron, or of the reduced iron, thus $2 CO = C + CO_2$.

It would therefore appear that the whole of the gas issuing from the blast furnace ought to consist of CO_2 and N, but it should be remembered that if the temperature be sufficiently high, the CO_2 will be brought back to the state of CO by contact with the coal, and although every effort is made to prevent this last named re-action, which entails an additional expenditure of fuel, a mixture of CO, CO_2 and N is always found at the furnace mouth. The ratio of CO_2 to CO by weight is regarded as an indicator of the working of the blast furnace. The higher this is, the less will be the quantity of carbon consumed, and an ideal working corresponds with a value of this ratio = 0.78, because one volume of CO_2 + one volume of CO represents a gaseous mixture that exerts no action on the oxides. It may therefore be said that the ratio 0.7 to 0.8 represents a satisfactory reduction of the ore in the absence of special circumstances.

The ratio of CO_2 to CO cannot, however, serve as a comparison of furnaces working under different conditions, because this ratio varies with the nature of the ore used, the pig iron to be produced, the fuel and temperature of the blast and the capacity of the fur-

nace. The proportion of combustible particles varies according to circumstances, and the same is the case with their calorific power. Lastly the quantity of gas given off with the production of one ton of pig iron is not absolutely constant for one and the same furnace, but increases as the proportion of CO_2 to CO becomes higher.

The calorific power of the gas can be measured by the Mahler shell, the eudiometric bomb of Professor Witz, or the Junker calorimeter, and the quantities of gas are arrived at directly by a knowledge of their mean speed in a given channel. Professor Witz has found that the heat given out by the complete combustion of a cubic



1,200 H. P. Cockerill Gas Engine.

metre of gas from four Cockerill blast furnaces in Europe varied from 978 to 1000 calories (mean 3968 B.T.U.'s), and M. Meyer that the heat of combustion from two furnaces at Differdange varied from 936 to 950 calories (mean 3742 B.T.U.'s). Analyses from American practice show that the calorific value of the gas is about 90 B.T.U.'s per cu. ft. It might be stated here that in American practice the general method of estimating the amount of gas produced is by measuring the amount of air blown in, by knowing the size and speed of the blowing engines, and basing the calculations on this.

The following example will serve to illustrate a method of calculating approximately the amount of gas produced by a given furnace.

Data.

Coke—good hard coke, 85% fixed carbon.

Limestone—42% CO_2 containing 115 lbs. carbon per 1,000 lbs.

Pig Iron Analysis—Fe, 94.00%; C, 3.75%; Si, 2.00% S, P, etc., 0.25%.

Furnace Gases—Analysis by volume, with weights calculated upon the basis of 1,000 cu. ft.

$CO_2 = 11.7\%$; 1,000 cu. ft. = 13.572 lbs.
CO = 27.5%; 1,000 cu. ft. = 20.268 lbs.
$H_2 = 0.8\%$; 1,000 cu. ft. = 0.042 lbs.
$N_2 = 60.0\%$; 1,000 cu. ft. = 78.139 lbs.

Furnace charge—To produce 1 ton pig iron:

Ore	3,400 lbs.
Coke	2,000 lbs.
Limestone	1,000 lbs.

Calculation.

All the carbon charged into the furnace must appear in the pig iron produced, and in the furnace gases evolved. The furnace charge contained in 2,000 lbs. coke, 1,700 lbs. carbon, and 1,000 lbs. limestone, 115 lbs. of carbon, making a total of 1,815 lbs. carbon.

The 2,000 lbs. pig iron produced from the above charge contained $2{,}000 \times 0.375 = 75$ lbs. carbon, therefore for each ton of pig iron produced there went to the gas $1{,}815 - 75 = 1{,}740$ lbs. carbon; also 1,000 cu. ft. gas contain 12.335 lbs. carbon, as calculated from the gas analysis (there being 3.70 lbs. carbon in 13.572 lbs. CO_2 and 8.685 lbs. carbon in 20.268 lbs. CO), hence there will be evolved for each ton of iron $\frac{1740}{12.335} \times 1{,}000 = 141{,}000$ cu. ft.

By this method of calculation, Mr. Campbell of the Pennsylvania Steel Co., has made the following table showing the volume and composition of tunnel head gas under different conditions:

Practice	Ratio CO_2 : CO	Per Ton Pig Iron Lbs.		Carbon per Ton Iron		Carbon in Gases per Ton Iron Lbs.		Weight per Ton Iron Kg.		Oxygen per Ton Iron Kg.			
		Coke	Stone	In Coke and Stone	In Pig Iron	In Gases	In Gases	As CO_2	As CO	CO_2	CO	In Gases	From Ore	From Stone	From Blast by difference
				lbs.	lbs.	lbs.	kg.								
A	1.5	1,600	600	1,464	84	1,380	627	251	376	920	877	1,170	415	88	667
B	1.5	1,600	1,000	1,512	84	1,428	649	259	390	950	910	1,211	415	147	649
C	1.7	1,900	1,000	1,773	84	1,689	768	284	484	1,041	1,129	1,402	415	147	840
D	2.0	1,900	1,000	1,773	84	1,689	768	256	512	939	1,195	1,368	415	147	806
E	1.7	2,200	1,000	2,034	84	1,950	886	328	558	1,203	1,302	1,619	415	147	1,057
F	2.0	2,200	1,000	2,034	84	1,950	886	295	593	1,082	1,384	1,580	415	147	1,018
G	2.25	2,500	1,000	2,295	84	2,211	1,005	309	696	1,133	1,620	1,752	415	147	1,190
H	2.5	2,500	1,000	2,295	84	2,211	1,005	287	718	1,052	1,675	1,722	415	147	1,160
I.....	2.5	3,000	2,000	2,850	84	2,766	1,258	360	898	1.320	2,095	2,157	415	296	1,446

Practice	Weight of Nitrogen per Ton Pig Iron, calculated from weight of Oxygen	Volume of Gases per Ton Iron Cubic Metres			Composition of Gases Per cent.			Volume and Heat Value per Ton Iron		
		CO_2	CO	N	CO_2	CO	N	Volume Cubic Metres	Heat value Calories per Cubic Metre	Heat value per Ton Iron Calories
	kg.									
A	2,208	467	702	1,752	15.99	24.03	59.98	2,921	736	2,150,000
B	2,148	482	728	1,705	16.54	24.97	58.49	2,915	764	2,227,000
C	2,780	528	903	2 206	14.52	24.83	60.65	3,637	760	2,764,000
D	2,668	477	956	2,118	13.43	26.92	59.65	3,551	823	2,922,000
E	3,499	611	1,042	2,778	13.79	23.51	62.70	4,431	720	3,190,000
F	3,370	549	1,107	2,675	12.68	25.56	61.76	4,331	782	3,387,000
G	3,939	575	1,299	3,126	11.50	25.98	62.52	5,000	794	3,970,000
H	3,840	534	1,340	3,048	10.85	27.23	61.92	4,922	826	4,066,000
I.....	4,786	670	1,676	3,798	10.90	27.28	61.82	6,144	818	5,026,000

Assumptions { Coke, 87% carbon; Limestone, 97% $CaCO_3$; Pig Iron, 95% Fe and 3.75% C. Tunnel Head Gas contains 0.5% H.

From this table we can obtain the amount and calorific value of the gas, knowing the ratio of CO_2 to CO, and the quantity of materials charged to produce one ton of pig iron.

One of the chief objections against the direct use of blast furnace gas in engines has been on account of the quantity of fine dust held in suspension, which if allowed to enter the cylinder immediately begins to wear it away. Immediately after passing from the blast furnace, the gas is submitted to a varying amount of purification to keep as much dust as possible from the hot blast stoves. The amount of purification of the gas before reaching the engine varies according to the magnitude and general arrangement of the plant. At Differdingen, for example, the gas is thoroughly cleaned at the furnace, and any further cleaning before reaching the engine becomes unnecessary. It is a general fact that different systems and designs of gas engines vary very much in their sensitiveness to furnace dust. It is also known that the quality and quantity of the gas depends to a large extent on the ores being smelted.

There are two main methods of cleaning the dust from the gas and removing the moisture, namely, the Thwaite and Theisen methods, and all purification plants are modifications of one or the other or both of these methods. The Thwaite method consists in passing the gas through a series of scrubbers or sheet iron towers containing coke or sawdust. The Theisen method consists in passing the gas through a centrifugal fan where it meets a stream of water, causing the dust and water, in the form of mud, to be thrown against the side of the fan while the gas passes through.

We shall now proceed to give descriptions of gas purifiers in use at different plants with results of tests made on them.

At Friedenshütte the gas first passes through three circular dry purifiers 7 ft. in diameter, and 70 ft. high, and then up and down through five small purifiers 6½ ft. wide, 10 ft. long and 45 ft. high. All are closed with water seals at the bottom and the total length of pipe used is 690 ft. From here the gas goes to the purifying plant, where the fine dust and steam are removed. This consists of purifiers 44 ft. high, 13 ft. broad and 42½ ft. long, separated into

two vertical rows each containing eight divisions. The gases are led up and down through both rows, water being injected from above. Here the gas is cooled from 320° F., the furnace temperature, to 62° F., and this cooling removes 137 of the 165 grams water contained in each cubic metre of the gas as it comes from the furnace. The volume of cooling water is $\frac{1}{100}$ the volume of the gas, and 10,000 cubic metres of gas are treated per hour.

The gas now goes to another set of purifiers, which are iron boxes with two wooden gratings, closed with a wrought iron cover, with a water seal. On the grating is a coarse piece of sacking and then a layer of sawdust. The gas enters from above through a valve, passes through two layers of sawdust and leaves the box through another pipe. Each box has a water collector, each set of four boxes a common admission pipe, and each set of eight boxes a common discharge pipe. In all there are sixteen boxes and in these boxes a square metre of surface for a cubic metre of gas per minute is used. From these boxes the gas goes to the holder and thence to the engine. On entering the holder the gas contains 0.002 grams dust and 5.5 grams water per cubic metre, and the temperature is 48° F., while on coming from the furnace the gas contains from 5 to 20 grams dust and 165 grams water per cubic metre, and has a temperature of 320° F. It may thus be seen that as far as clearing the gas, this type of purifier is very efficient, but the whole plant would be very large if much gas were to be purified.

Another type of purifier is at the Micheville Iron and Steel Works in Meurthe-et-Moselle. Here there are six vertical cylindrical pipes 62 ft. high, three of them 8 ft. in. diameter descending and three 13 ft. in diameter ascending, which communicate two by two and alternately above and below. The bottom, in the form of a truncated cone, has an arrangement for emptying which permits of cleaning two columns at once. The gas enters the first pipe, strikes the surface of the water and ascends, then descends and so on.

At some iron works, dry purifiers are employed and at others there is a sprinkling of water where the gas rises in the last column.

At the Ormsby Iron Works in England, where from 29 to 35 cubic metres of gas are used per minute, the gas is cooled and purified by a long pipe and a centrifugal fan. The pipe is 5 ft. 6 in. in diameter and 1,100 ft. long and a 36 in. centrifugal fan is driven by an 18 H. P. motor at from 750 to 1,200 R.P.M. The temperature of the gas coming from the furnace, is 510° F., and at the end of the long pipe 84° F., and after going through the fan 62° F. In one case 500 gallons of water were used in the fan to purify 2,400 cubic metres of gas, the fan running at 1,150 R.P.M. With the fan running at 700 R.P.M. and using 850 gallons of water per hour, the temperature of the gas was found to be 55° F. on leaving the fan and it contained 0.525 grams dust per cubic metre. It has been found at this plant that the best results are obtained with a fan speed of 1,100 to 1,150 R.P.M., and with 500 to 600 gallons of water per hour. In this fan the water enters along the axis of the shaft. After running for about 74 days it has been found necessary to clean the fan, it being so thickly coated with dust.

At Donnersmarck a 100 B.H.P. engine is used, and the gas is passed through a scrubber and a sawdust purifier. The scrubber was at first filled with coke in large pieces, and the gas entered from below and escaped at the top, and water was sprayed in under the cover of the scrubber. It was found, however, that the dust particles separated from the gas soon began to hinder considerably the passage of the gas through the coke, and that the scrubber had to be frequently cleaned. For this reason the coke was done away with and only the water spray used, and the results have been found to be equally satisfactory. The deposited dust escapes continuously from the scrubber in the form of thin mud, through a syphon tube. The dust collected here amounts to about 3.3 lbs. per 100 H. P. per day. The gas then passes through the sawdust purifier in which are two layers of sawdust about 4 in. or 6 in. thick, and through these the gas rises. The sawdust has to be removed every four weeks, as by that time it is heavily charged with dust. The gas leads also act as dust collectors, and have to be cleaned every Sunday. From 91 to 99 cubic feet of gas is used in the engine per horse power per hour.

A Theisen centrifugal gas washer is in use at Hörde. It is cylindrical in form, about 5 ft. in diameter and 15 ft. long. It is placed about 16 ft. from the main gas lead, which serves three blast furnaces, and about 361 ft. from the nearest of these. There is a pressure of about 1 in. to 1½ in. in the gas main, and from it the gas is exhausted by the washer, and driven forward with a pressure of from 4.7 in. to 5.9 in. of water column, into a collecting main for the purified gas, from which the engines are supplied. Before entering the washer, the gas contains 3.34 grams dust per cubic metre, and after washing about 0.010 grams. The wash water amounts to about a litre per cubic metre of gas washed, and about 100 cubic metres are passed through the washer per minute. The moisture in the gas dropped from 36.21 grams per cubic metre before entering the washer to 3.013 grams on leaving.

At Differdingen a Theisen apparatus is used, the water entering along the axle of the fan. The gas first passes through a scrubber and then enters a fan 39½ in. in diameter, and then one 59 in. in diameter. A test was made with the following results. Gas entering static purifier contained 10.6 grams per cubc metre, and on leaving it contained 5.3 grams, and part of this was deposited in the pipes, leaving 2.7 grams in front of first fan and 1.5 grams on entering the second, and 0.23 grams on leaving the second fan; the temperature of gas was reduced in first fan from 115° F. to 104° F. The small fan ran at 1,600 R.P.M. and the large one at 800 R.P.M. Treating from 150 to 1,000 cubic metres per minute, the power required to drive the fans varied from 15 to 90 B.H.P. The water required was about one litre per cubic metre of gas. At this plant the dirty water runs into settling tanks, each of which holds 60 cubic metres and receives the water from 3,000 H. P. of engines for about 4½ hours. Here the dust settles to the bottom, and the water is used over again.

In all the earlier types of centrifugal washers the axis of the fan shaft was vertical, and the water was run in along the shaft. This type is the one used in the purification plants just described, except the one at Hörde. In 1901 Mr. Theisen invented a new type of centrifugal washer, in which the gas is impelled by centrifugal

force over a film of water circulating rapidly over the inside of a cylindrical surface in the opposite direction to the current of gas. The size of one machine of this type is 9 ft. inside diameter, and 11 ft. long. The rotating cylinder makes 300 R.P.M. and the gas is brought into contact with 200,000 sq. ft. of washing surface per minute under a pressure of 6 in. of water. Mr. Theisen calculated that about 40 H.P. would be required to drive the apparatus when cleaning 6,000 cubic metres per hour.

An apparatus of this kind is used at the Schalk Mining and Smelting Co., and a test made on it in 1903 gave the following results. Gas entered at 140° C. containing 2.5 grams dust per cubic metre. Using 55 to 60 H. P., the apparatus cleaned 115 cubic metres of gas per minute, leaving in it only 0.008 grams dust per cubic metre, and 15 grams moisture. In this plant the volume of water used was one litre per cubic metre of gas. The dirty water escaped at 50° C., and was cooled in settling tanks to 15° C. It was then used in an experiment over and over again for a fortnight, and at the end of this time the dust in the cleaned gas amounted to 0.022 grams instead of 0.008 grams as in the case where clean water was used.

A year or so ago Mr. Thwaite designed a new type of cleaning apparatus, which is used to a considerable extent in Europe. The gas is first led into a special form of washer of the simplest construction, as indicated in Fig. 1. It is equipped with a water seal, which not only enables the deposited dirt to be removed at any time, but also acts as a ready outlet in the case of sudden rushes of gas. This apparatus is so arranged as to compel the gases to flow uniformly and repeatedly through the water, this being effected by the action of the centrifugal fan in the engine-house, the position of which is indicated in Fig. 1. This fan maintains a 10 in. suction.

From the washer the gas goes into a vertical tubular condenser, shown in Fig. 1, which may act as a recuperator of hot air, if that should be required for any purpose. Usually, however, the pipes are cooled by the atmosphere. They are open on the top and bottom so they can easily be cleaned by flushing with water from an upper tank. This tank combines the

two sets of tubes through which the gas flows first upward and then downward. From this apparatus the gas enters the centrifugal fan to which reference has previously been made. This fan draws the

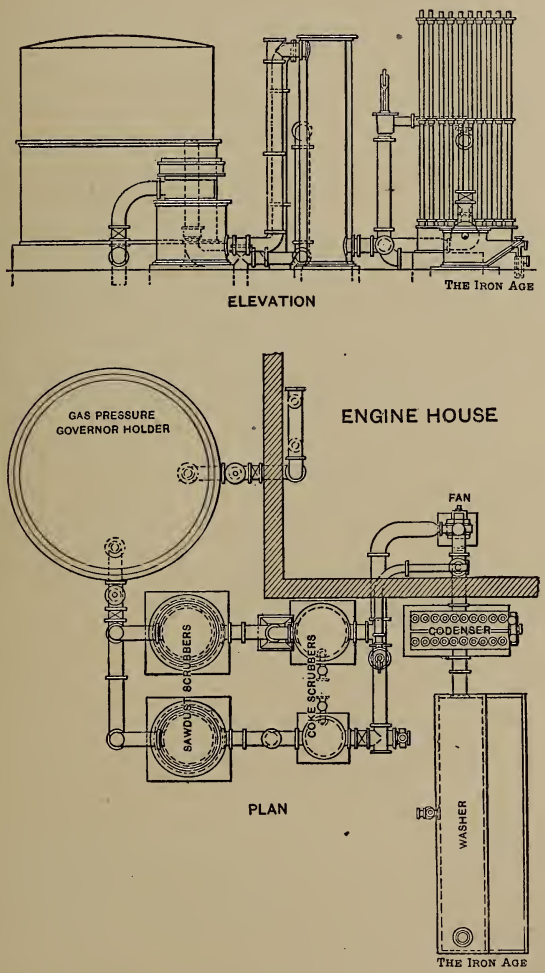


Fig. 1.

gas from the two parts of the plant described and forces it into two additional parts, the latter being mainly of use in case of an abnormal amount of dust in the gas due to explosions in the furnace. These

parts consist of sawdust and coke scrubbers, and on leaving them the gas enters the holder, which also acts as a pressure regulator.

In America, the only plant where gas is thoroughly cleaned is the Lackawanna Steel Co.'s at Buffalo. Here the dust first passes through the dust catcher and gas washer, the construction of which is familiar to most of you, and then enters a Theisen centrifugal apparatus, where the rest of the cleaning is done, and from which it goes to the gas holder.

These cases will be sufficient to show what progress has been made in cleaning the gas in Europe. The Theisen apparatus is certainly the more compact, but it consumes considerable power, and in case much dust was in the gas several fans would need to be used. The advantage of the Thwaite system is that the gas is not cooled to as low a temperature as is necessary with the other method, which is an advantage where part of the gas is to be used in boilers. The Thwaite apparatus is, however, much the larger, and is more costly to install than the Theisen.

The following calculations made by Mr. Scott of the Ormsby Iron Works, England, are sufficient to show the sensible heat lost by cooling the gas when it is being cleaned.

GAS SAMPLE.

$$\left.\begin{aligned} N &= 56.4\% \\ CO &= 28\% \\ CO_2 &= 15.5\% \\ H &= .07\% \end{aligned}\right\} \text{ by weight.}$$

Taking an amount of the gas such that the proportion of CO = 1 lb. by weight we get 2 lbs. N., 0.553 lbs. CO_2 and 0.0025 lbs. H.

Total heat in this amount of gas = 4480 B.T.U.'s.

Products of combustion are:

1.57 (from CO) + .553 (from CO_2) = 2.12 lbs. CO_2.

1.91 (to burn CO) + .067 (to burn H) + 2 (from N) = 3.977 lbs. N.

.0225 = .0225 lbs. H_2O.

Multiplying each of these by its specific heat and dividing into the total B.T.U.'s we get the temperature of combustion $= \frac{4480}{1{\cdot}440} =$ 3111° F. But perfect combustion is only possible with 20% excess of air, so temperature of combustion really is $\frac{4480}{1{\cdot}730} = 2589°$ F.

Now furnace gas temperature = 600° F., air temperature = 60° F., and proportions are 3.553 to 3.795, so the temperature of mixture = 318.3° F., hence total temperature of combustion = 2589 + 318 = 2907° F.

Now for the heat lost in cooling the gas. If 14112 lbs. gas are evolved in smelting 1 ton iron, then heat lost in cooling from 600° F. to 60° F. = 14112 (600 — 60) × .234 = 1783192 B.T.U.'s. Now 3.55 lbs. gas give 4480 B.T.U.'s, and ∴ 14112 lbs. $= \frac{14112}{3{\cdot}55} \times 4480 =$ 17809344.

Consequently the per cent. of total heat lost by cooling gas $= \frac{1783192}{17809344} = 10\%$ approximately.

The temperature caused by uncleaned gas is 2907° F., and by cleaned gas, is 2589° F., so that loss in temperature = 14%.

A number of difficulties were expected in operating gas engines beside the dust trouble, the main ones being the low calorific power of the gas and its varying quality. The trouble due to varying quality is, however, easily overcome by mixing together the gases from three or four furnaces. It was feared that there would be difficulty in igniting furnace gas, which burns but poorly under boilers, but in compressing gas and air mixtures, an operation which goes on in the engine cylinder during the second stroke of the cycle, a means is available to cause a certain ignition of even very weak gas.

It might be thought at first sight that the low calorific power of the gas would necessitate the use of very large cylinders, but the following example shows that this is not the case. A cubic foot of blast furnace gas having a heating value of 98.5 B.T.U.'s per cubic foot requires for combustion a cubic foot of air, making 2 cubic

feet of mixture, having a total heating value of 98.5 B.T.U.'s. Also a cubic foot of good lighting gas having a heating value of 585 B.T.U.'s per cubic foot requires 7 cubic feet of air for combustion, and 2 cubic feet of this gas then give a heating value of 146 B.T.U.'s, so that to develop the same power, the cylinder of a blast furnace gas engine must be 1½ times as large as the cylinder of an engine using good lighting gas.

Gas Engines.

In the comparison of gas engines a series of considerations must be taken into account, which are here enumerated in the order of importance.

1. Security in operation.
2. Quiet running.
3. Accessibility of those parts which must be frequently inspected and cleaned.
4. Regulation.
5. First cost.
6. Consumption of lubricants.
7. Number of B.T.U.'s per horse power per hour.
8. Space occupied.
9. Points affecting coupling to dynamos.
10. Consumption of water.
11. Balancing of masses.
12. Elegance of design.

In dealing with gas engines we shall first take up engines of the Otto four-cycle type. These engines are generally made without guides or cross-heads. This type of motor is of course cheap to construct, but has many disadvantages. The piston has as a rule from five to ten piston rings, and these rings, in presence of the unavoidable residues of combustion, wear the cylinder considerably. The wearing of the piston is usually so large in the first few months that accurate fitting has become valueless. The piston acting as a cross-head thus becomes loose in the cylinder, and during the compression stroke it

is lifted and then falls back again. In case of small engines the blows thus created are not of importance, but are very troublesome in large engines. By this construction also the cross-head bearing, one of the most difficult details in large engines, is placed in the hot piston which causes it to be troublesome. For large powers then, only engines with guides and cross-heads should be used.

One of the best known engines of the Otto four cycle type is the Deutz engine, used considerably in Germany. Generally the maximum capacity of a single cylinder of this type is limited to 250 to 300 H. P., so that large powers are obtained by using a number of cylinders. In the single-acting engine, which is the most common, the cylinder head has one admission and one exhaust valve, placed in such a way that the admission valve is in the upper part and the exhaust valve in the lower part of the inner wall. Since the engine

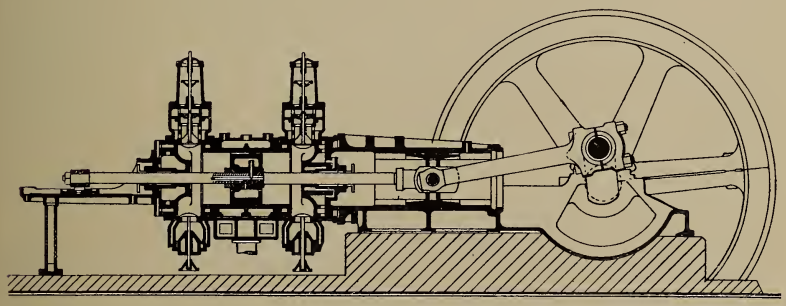


Fig. 2.

does not generally have piston rods which pass through the cylinders, the exhaust valve, which is cooled by its hollow spindle, is accessible after removing the upper valve box. The valves are operated by cams from the valve gear shaft. The governing is done by throttling the supply of gas and air mixture in such a way that by simultaneously changing the sections of the gas and air passages, the mixture remains the same and only a larger or smaller quantity enters the cylinder. This type of engine has as a rule the following general dimensions:

(1) Stroke $\frac{3}{8}''$ per I. H. P. for 100 H. P. down to $\frac{5}{64}''$ for 800 I. H. P.

(2) Circumference of cylinder $\frac{11}{64}$" per I. H. P. for 100 H. P. down to $\frac{3}{16}$" for 800 I. H. P.

(3) Piston area 4 sq. ins. per I. H. P. for 100 H. P. down to 2.65 sq. ins. for 800 I. H. P.

Fig. 2 shows a cross-section through a double acting engine of this form.

Generally two engines of this type are connected together, the cylinders being on opposite sides of the shaft and the two connecting rods being attached to the same crank. For driving dynamos it is usual to take two pairs of engines so attached together, the two pairs of connecting rods being attached to the same shaft on which the armature revolves.

Another type of gas engine, known as the "Simplex" engine, has been used very extensively in blast furnace work, there being in October, 1903, as much as 97,430 H. P. of these engines either being built or in use in England and the continent. Fig. 3 shows a double-acting engine of this type direct connected to a blowing cylinder. At the front end of the engine is shown the admission valve for the gas and air which form the explosive mixture; the operating gear for this valve is also drawn. Air is taken in through the angular chamber just below the valve seating, while the gas is admitted through the opening shown on the right hand side. The gas thus passes into the centre and is surrounded by the annular space containing air; then both ascend and mix as they pass the valve, the latter being worked by a cam actuated by eccentrics. Below is a dash pot for regulating the closing of the valve so as to give it easy motion. The speed of the engine is controlled by a ball governor mounted on the framing which, by regulating the valve, gives a variable cut off.

Ignition takes place in the explosion chamber above the inlet valve, an electrical igniter being used. The sparks, which are continuously produced from a Ruhmkorff coil, supplied by storage cells, are made to pass between points in a closed chamber, and the latter is only put into communication with the cylinder when ignition is required.

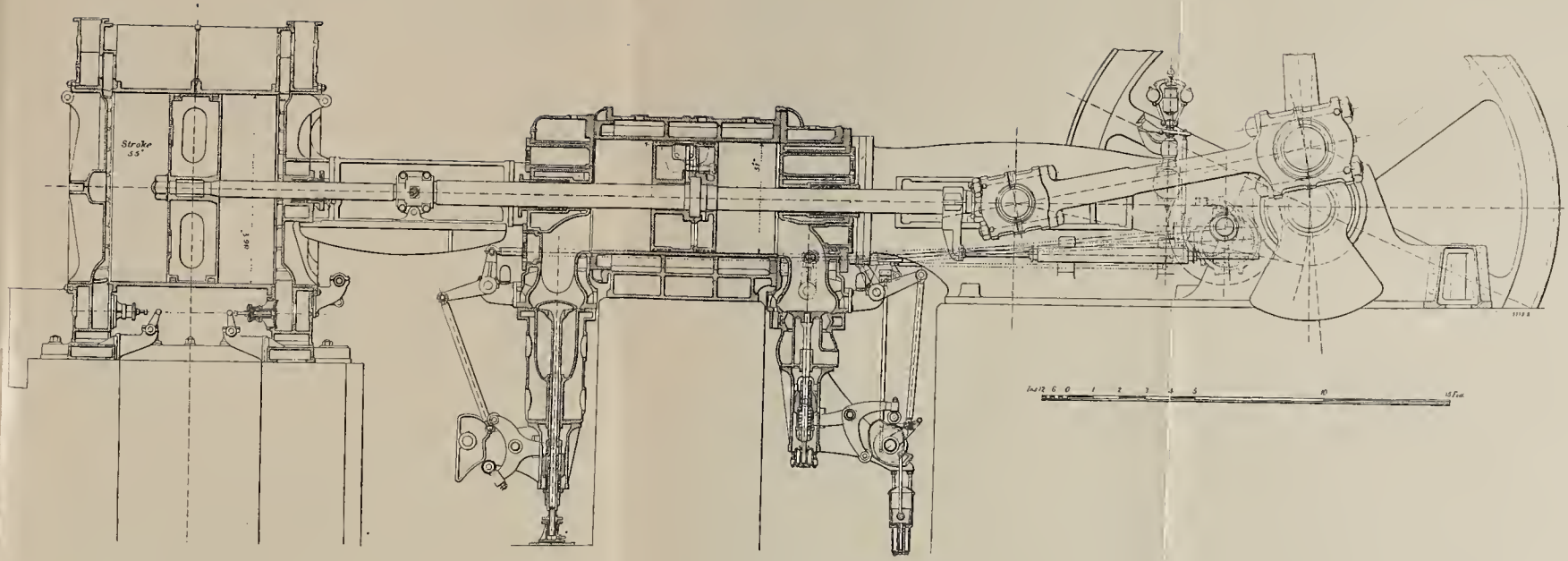


FIG. 3.

The exhaust chamber as well as the valve and spindle are water-jacketed. The cylinder is also water-jacketed both on the barrel and ends. The piston is also water cooled, the water entering through the cross-head into the hollow piston rod, and from there to the piston. There are divisions to insure a proper circulation so as to cool the whole surface, the water escaping through the back cross-head.

These engines are made single cylinder, single acting; tandem cylinders, single acting; and tandem cylinders, double acting; also single cylinder, double acting; the two cylinder engines being mostly used for driving dynamos.

The following table gives examples of the various types of the Cockerill engine, giving the speed variations for the different types and sizes.

Horse Power	System	R.P.M.	Diam. Cylinder Inches	Stroke Inches	Regularity	
					Absolute	Cyclical
100	Single-cylinder	150	23.62	31.5	35	60
225	Tandem	150	23.62	31.5	41	80
450	Double-tandem	150	23.62	31.5	52	210
200	Single-cylinder	150	29.5	35.5	42	78
425	Tandem	150	29.5	35.5	50	96
850	Double-tandem	150	29.5	35.5	65	260
300	Single-cylinder	130	35.5	39.37	63	110
650	Tandem	130	35.5	39.37	77	150
1300	Double-tandem	130	35.5	39.37	100	400
475	Single-cylinder	100	43.3	47.2	62	105
1000	Tandem	100	43.3	47.2	74	140
2000	Double-tandem	100	43.3	47.2	95	380
600	Single-cylinder	90	51.2	55.11	19	30
1250	Tandem	90	51.2	55.11	22	43
2500	Double-tandem	90	51.2	55.11	29	120

Note.—The cyclic speed variation is equal to the maximum angular velocity, minus the minimum angular velocity, divided by the mean angular velocity. The reciprocal of this is the regularity given in the last column. When the governor cuts out one admission of gas the regularity is diminished and is then called the "absolute regularity," as shown in the last column but one.*

At the Kladus Steel Works in Bohemia a 600 H. P. Cockerill engine, with four single-acting cylinders, is coupled to a 450 kilowatt

*H. A. Humphrey, Institution Mechanical Engineers, 1901.

three-phase generator, working in parallel with two-steam driven generators. The speed is 150 R.P.M., and the frequency 25 cycles per second. The cyclic variation is $\frac{1}{200}$ with a fly-wheel 18 ft. diameter, and weighing 28 tons. At first only one-half the complete engine was set to work, and the cyclic variation was then $\frac{1}{130}$, but the alternator ran well in parallel with the steam engines.

At this plant there is an electric eddy current brake, which is applied to the flywheel in order to provide an artificial load up to some 300 horse power, when putting the generator in parallel with the others. The brake is very simple and consists of an electro magnet requiring but little energy in the shape of a small amount of direct current which can easily be regulated in strength according to the brake power wanted. In addition there is provided an adjustable three phase choking coil to limit the synchronizing currents during the adjustments. Both the brake and the choking coil are put out of use when the alternator has taken up its load.

These figures are sufficient to show that these engines can be made to drive alternators in parallel.

Several tests have been made to determine the efficiency of the engines, the water and oil used, etc., and the following is one of these tests made by Professor Witz on a 200 H.P. gas engine at Seraing.

Dimensions of Engine.

Cylinder diameter	31.5 in.
Piston stroke	39.37 in.
R. P. M.	105

Hit and miss governor.

Results.

Length of test	24 hrs.
Average B. H. P.	178.6
Mechanical efficiency	85%
Temperature of air	27°, 15° 17.5° C.
Temperature of gas	27°, 18°, 21° C.
Inlet temperature of jacket water	22.7° C.
Outlet temperature of jacket water	33.7° C.

Consumption of Water.

Cleaning gas, per hour .....1185.3 imperial gals.
To cool cylinder, per hour.....2,860 imperial gals.
Total water per B. H. P. per hour .....22.4 imperial gals.

Consumption of Oil and Grease.

Per 24 hours, oil.....149.9 lbs.
Per 24 hours, grease .....4.4 lbs.

Consumption of Gas.

Volume of gas at 0° C. and 760 mm. per hour.....21,362 cu. ft.
Brake horse power 179.2
Thermal efficiency on B. H. P. 19.4%

Following are the results of tests on a "Simplex" blowing engine, at the Ormsby Iron Works, in England, in 1902.

Data Regarding Engine.

Single cylinder, direct connected to double-acting blowing cylinder; electric ignition; exhaust valve, main bearings and cylinder cooled by water under 60 ft. head; piston also cooled.

Gas cylinder .....4 ft. 3 in. diam.
Blowing cylinder .....5 ft. 7 in. diam.
Stroke .....4 ft. 7 in.
Normal speed .....78 R.P.M.
Air pressure .....7 pds. per sq. in.
Fly-wheel—2 pieces .....16′—6″ diam.; weight, 33 tons.

Engine weighs 160 tons, and occupies floor space 52 ft. 6 in. x 21 ft. 9 in.

Water usually used in cylinder, etc., for cooling = 8,800 Imperial gallons per hour, but in this case 25,398 gallons per hour were used with resulting increase of only 6° F. between inlet and outlet.

FIRST TEST—*Blowing Cylinder Disconnected.*

Calorific value of gas = 110.6 B. T. U.'s per cu. ft.
Thermal efficiency, full load, on I. H. P. = 25.2%.
Thermal efficiency full load, on B. H. P. = 20.48%.

SECOND AND THIRD TESTS—*Blowing Cylinder Connected.*

Calorific value of gas per cu. ft., 117.3 and 112.8 B. T. U.

Average sample of gas:

$N = 56.28$ $CO_2 = 15.96$

$CO = 27.7$ $H = .06$

Ratio $\frac{CO_2}{CO} = .576.$

I. H. P. .....746.21 and 886.5

R. P. M. .....84 and 93

H. P. in compressed air .....562.5 and 725.6

Pressure of air in compressor in mm. mercury .....394 and 450

Mechanical efficiency .....75.41% and 81.81%

Volume of gas consumed per minute at 0° C and 760 mm.

cubic metres .....= 29.19 and 34.48

Thermal efficiency referred to I. H. P. .....27.34% and 27.11%

Thermal efficiency refered to work done in compressing air = 20.4% and 22.17%.

In these the figures first given are for the second test and those given last are for the third test. Motor running light absorbed 147.36 H. P. Heat converted into work in cylinder = 28% average for the two tests. Heat carried away by circulating water = 52% average. Heat carried away by gases and losses = 20%.

Several tests were made by Professor Hubert on a 600 H. P. "Simplex" Gas Engine, at Seraing, as follows:

Engine.

Piston diameter .....51.19 in.

Piston stroke .....55.13 in.

Shaft diameter .....18.11 in.

Space occupied .....36.1 ft. x 19.7 ft.

Weight of fly-wheel.....32.5 tons

Total weight of engine.....124.9 tons

Results.

I. H. P. 786.16

B. H. P. 575.00

R. P. M. 94.37

Mechanical efficiency 73.14%
Volume of gas used per minute at 0°C and 760 mm.....1,183 cu. ft.
Volume of gas per I. H. P. per hour.....90.27 cu. ft.
Volume of gas per B. H. P. per hour.....123.45 cu. ft.
Consumption of water per B. H. P. per hour in cylinder..12.5 gals.
Inlet temperature .....46.15° F.
Outlet temperature .....91.71° F.
Consumption of water per B. H. P. per hour in piston....2.8 gals.
Average temperature of gas at inlet.....48.2° F.
Average temperature of gas at outlet.....947.3° F.

These tests are sufficient to show the efficiency of this type of engine, which is at the present time very commonly used in blast furnace work.

We now come to the Oechelhäuser two period motor. In this engine there is a long horizontal water cooled cylinder in which are two pistons working in opposite directions. The front piston is attached by its connecting rod to a crank set at 180° to two other cranks, which are driven by the connecting rods attached to the cross-head of the back piston. This back piston cross-head also works the piston of a double-acting air pump, delivering pure air on one side and mixed gas and air on the other. There is no valve shaft and practically no valves, the pistons opening and closing the admission and exhaust and being so arranged as to prevent any possibility of any of the exhaust gases remaining in the cylinder to mix with the fresh charge. Fig. 4 will make the construction of the engine clearer.

The cycle of the engine is as follows: The two pistons being as close together as possible, and the space between them being filled with a mixture of gas and air at a pressure of 135 lbs. per sq. in. absolute, the charge is fired electrically, and both pistons move out making the working stroke. As the main pistons nearly reach the end of their out stroke, the front one uncovers the exhaust opening and the other immediately afterwards, a port through which clean air, at a slight pressure, enters the cylinder and cleans it out. Next the same piston opens a second port by which the compressed charge

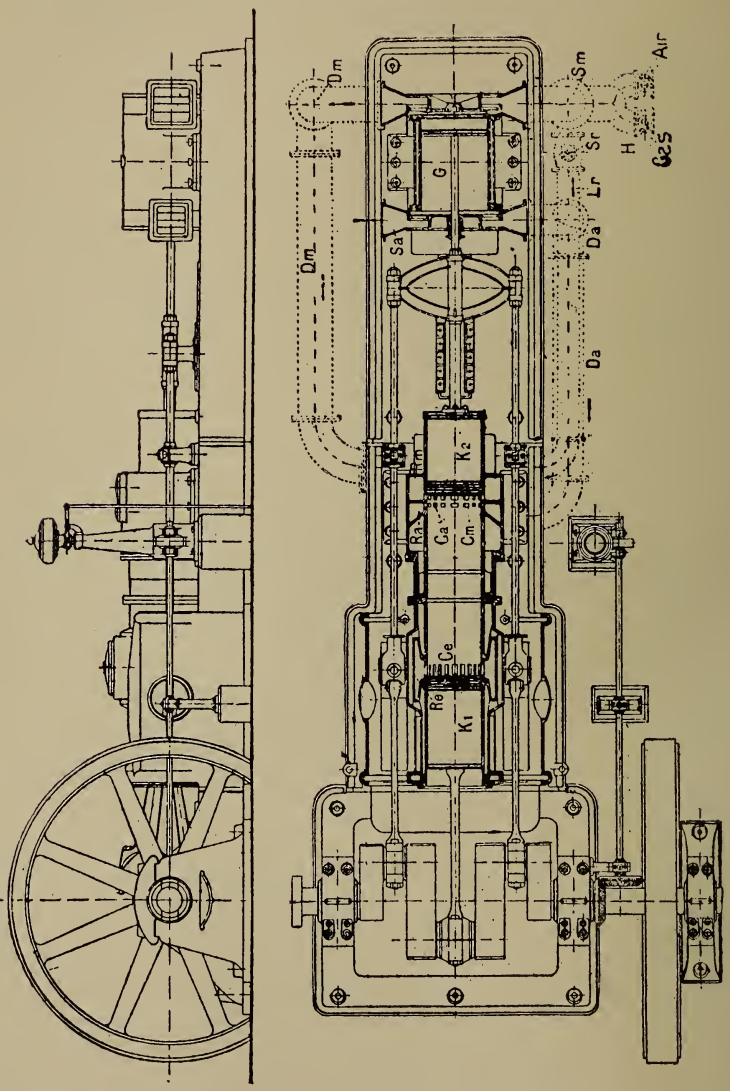


Fig. 4.

from the air pump enters, driving out the scavenging air. On the return strokes of both pistons, the ports are closed and the charge compressed ready to begin again.

Following are the most important general dimensions for this size engine.

(1) Stroke in ins. per I. H. P. = $\frac{7}{32}''$ for 200 H. P., down to $\frac{3}{32}''$ for 1,000 H. P.

(2) Circumference of cylinder in ins. per I. H. P. = $\frac{1}{4}$ in. for 200 H. P. down to $\frac{1}{8}$ in. for 1,000 H. P.

(3) Piston area in sq. ins. per I. H. P. = 1 sq. in. for 200 H. P. to 1,000 H. P.

The principal advantages of the Oechelhäuser type of engine are as follows:

(1) The small size of the cylinder for a given output.

(2) The rapid expansion following explosion.

(3) An impulse is obtained every revolution.

(4) The turning moment on the main shaft is produced by a couple, and the unbalanced forces transmitted to the bed plate are much less than in ordinary engines.

(5) The usual valves are dispensed with, as the pistons themselves act as slide valves.

The disadvantages are:

(1) The extra complication of motor and pump.

(2) The necessity of having three connecting rods, two crossheads and rods, and the pump gear; giving, together with the pistons, a large reciprocating mass per unit and of piston.

(3) The great length of the complete engine.

(4) The great distance between the main bearings, and the extra cost of the three cranks.

(5) The possible loss of gas, owing to some part of the explosive mixture blowing straight through before the exhaust port closes.

At Hörde, Westphalia, two 600 H. P. sets of this type of engine are used to drive dynamos, each 600 H. P. set consisting of two

separate 300 H. P. engines so that there is one direct-connected on each side of the dynamo shaft. The dimensions are:

Diameter of cylinders .....18.9 in.
Length of stroke.....31.5 in.
R. P. M. 135

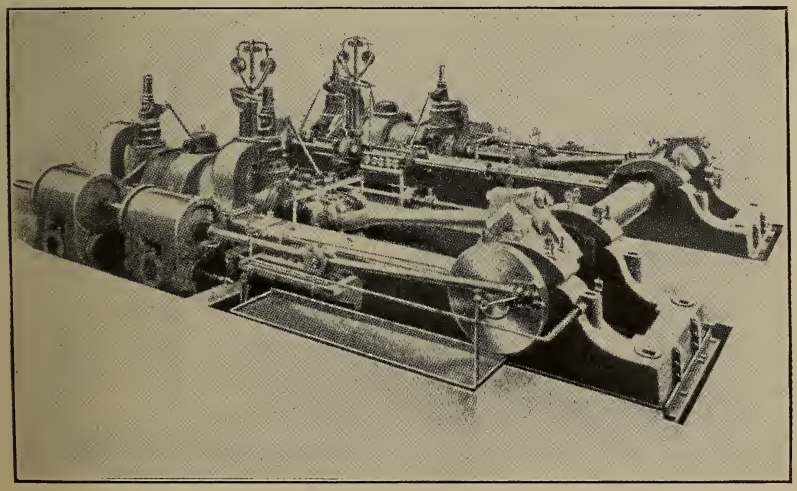
Mean effective pressure 66 lbs. per sq. in. The gas consumption as given by Prof. Meyer on a test on these engines is 124 cu. ft. per H. P. per hour.

The Oechelhäuser engine is very largely used for driving dynamos, nearly 80% of the engines now in operation being used for this purpose. A 1,000 horse power engine of this type, running at 125 R. P. M., only requires a 28 ton flywheel to limit its cyclic variation to $\frac{1}{350}$.

We now come to another type of two cycle gas engine namely, the Koerting engine. The cycle of this engine is as follows: Starting with the piston at the outer dead point the exhaust ports will be open to the other end of the cylinder. As soon as the exhaust ports are open, the pressure of the residual burnt gases drops rapidly to that of the atmosphere. The inlet valve to the cylinder is opened at this time and the air pump injects a quantity of air driving out the burnt products. This action takes place before any gas is admitted. The gas pump now delivers a charge of gas which mixes at the inlet valve with the proper proportion of air from the air pump, the piston having moved so as to close the exhaust ports in the meantime. The charge is compressed by the pumps to about 9 lbs. per sq. in., and further compressed by the return stroke of the piston to a much higher point. It is ignited at the proper time, driving the piston forward to the position shown. A similar operation of course takes place on the other side of the piston, and it is thus seen that the piston receives alternate impulses on either side as in a steam engine, the auxiliary cylinders performing the operations which in the case of four cycle engines are performed in the main cylinder.

The action of the gas and air pumps is shown diagrammatically in Fig. 5. A and B are the gas pump and air pump respectively.

By means of the piston valves *p p*, the ports *b b* are connected with the gas supply pipes *c c* during one portion of the stroke and with the passages leading to the inlet valves during the other portion. The throttle valves *f f* are under the control of the governor, as shown, and connect the ports *b b* with passage to inlet valve in main cylinder. It will be noted that the crank operating the pump pistons is 110° in advance of the main crank. The engine was first designed to govern through the piston valves opening the passage to the inlet valves sooner or later in the stroke of the gas pump, but it was



1,000 H. P. KOERTING ENGINE.

found that the excessive friction did not permit of the perfect regulation desired, so the throttle valves were added to assist in the regulation.

The main inlet valves are of the poppet type and are placed one at each end of the cylinder and are actuated by rods and links from a horizontal lay shaft running along the side of the engine frame, as shown in Fig. 6. The ignition gear is not fast, but is carried on a sleeve having a feather which is wound spirally around it, so that by sliding the sleeve along the shaft, the ignition contact is made

sooner or later as required. The regulation of the engine is controlled by the governor, which acts to vary the amount of gas admitted, by regulating the valve gear so that gas is delivered from the gas pump at a later part of the stroke, or by a by-pass located between each pump end and respective channel leading to the inlet valve in the main cylinder. A section of the engine is given in Fig. 7.

The valves, walls of the interior chamber, and stuffing box, are cooled by water. The piston is also water cooled, the water being forced in through the cross-head and along the hollow piston rod.

The ordinary general dimensions of this engine are:

(1) Stroke in ins. per I. H. P. = $\frac{5}{64}''$ for 500 H. P. down to $\frac{1}{16}''$ for 700 H. P.

(2) Circumference of cylinder in ins. per I. H. P. = $\frac{9}{64}''$ for 600 H. P.

The cylinder of this engine is then slightly smaller than for the Oechelhäuser type.

A 100 H. P. engine of this type was tested at Donnersmarch.

Data.

Cylinder diameter .....19.7 in.
Piston stroke .....33.5 in.
R. P. M. 130

Test.

Calorific value of gas .....1,000 calories per cu. metre
Cubic feet of gas per B. H. P. per hour.....91 to 99
Oil used per day.....6 lbs.
Cooling water per day .....2825 to 3530 cu. ft.

About 40,000 H. P. of these engines is at present being constructed for the Lackawanna Steel Co., at Buffalo, New York. At present four or five of these engines are running. They have cylinders 24¾ in. diameter, and 43¼ in. stroke, and develop 1,000 H. P. at 100 R. P. M., and are used to drive dynamos. Average composition by volume of gas used: CO = 24%, N = 60%, CH_4 = 2%, CO_2 = 12%, H = 2%. Calorific value of gas 90 B.T.U.'s per cu. ft.

The following table compares three engines of approximately the same power with regard to size of cylinders, etc.

Type of Engine	Number of cylinders	Diameter of cylinders	Stroke	Maximum horse-power	Weight without fly-wheel—Kilogrammes	Weight with fly-wheel—Kilogrammes	Revolutions per minute	Cyclic variation
		M.M.	M.M.					
Cockerill Engine, single-cylinder	1	1300	400	600	94,000	127,000	90	1 : 30
Deutz four-cylinder, "Otto" cycle	4	660	850	600	88,000	100,000	150	1 : 130
Koerting Engine, single-cylinder, double-acting	1	635	1100	550	58,000	70,000	100	1 : 80

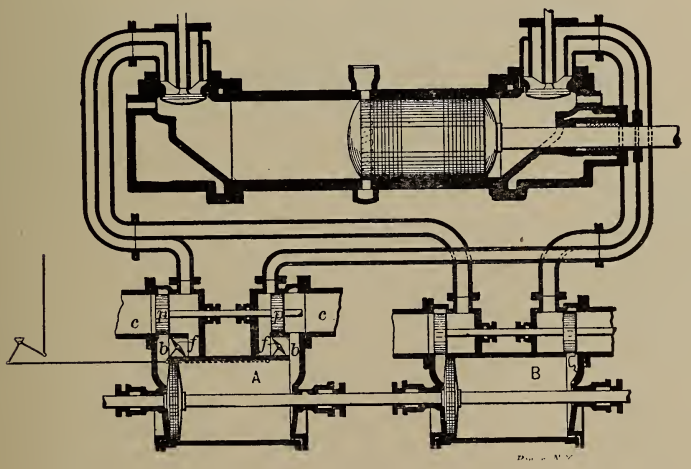


Fig. 3.

To start these large engines, compressed air, stored in strong vessels carrying 80 to 150 lbs. pressure, is generally used; and a special inlet valve and gear is fitted to at least one cylinder, which automatically controls the air supply while the speed is being raised. It is the simple pressure of the air which effects the starting, no explosions taking place. When the engine has attained sufficient speed, gas is supplied to one of the other cylinders in the usual way, and the compressed air is no longer required. If the engine has only

one cylinder, the flywheel carries on the running, while the change from compressed air to ordinary explosive mixture is made. The Cockerill Company, however, seem to prefer to fit a special benzine vaporizer to supply carburetted air for starting, an electric motor and barring gear being also available.

The methods of electric ignition are first, by the interruption of a current flowing through an induction coil enclosing a good deal of iron; second, by the breaking of a current, at its maximum strength, supplied by a shuttle armature oscillating between permanent magnet poles. A third method used only by the Cockerill Company has already been described.

Some have objected to the use of the blast furnace gas engine for driving blowing cylinders on account of its high speed, the ordinary speed of steam blowing engines being only about 44 or 45 R. P. M. while the speed of the gas engine is 90 R. P. M. or over. It has been found, however, that Corliss valves work well on the inlet side, and Riedler Stumpf valves on the delivery side. The latter valve is shown in Fig. 8, and consists of an annular clack resting directly on the inner side of the cylinder covers, being connected by a tube with an annular disc of larger area, which butts against a solid plate (without holes). When the piston begins to compress air, the latter enters by the tube, under the disc, forcing the disc in a backward direction, since its area is greater than that of the clack. The latter opening into the inside of the cylinder, allows the compressed air to escape into the pipe until the moment when the piston, having reached the end of its stroke, mechanically obliges the valve to close, the shock being cushioned by a little air left under the disc and also by the springs. This simple valve permits working at as high as 300 R. P. M.

Saving Effected.

Let us now see what saving is effected in the steel plant by the use of blast furnace gas engines. Let us divide the discussion into four parts, as follows:

A, If the blast furnace gas is displaced in the hot blast stoves by the use of producer gas, releasing the former gas for motive power, without interfering with the steam blowing outfit.

B, The same conditions but replacing the steam boiler, and steam driven outfit by gas driven.

C, Assuming the prevention of the waste of blast furnace gas during charging operations, and the power utilization of the gas.

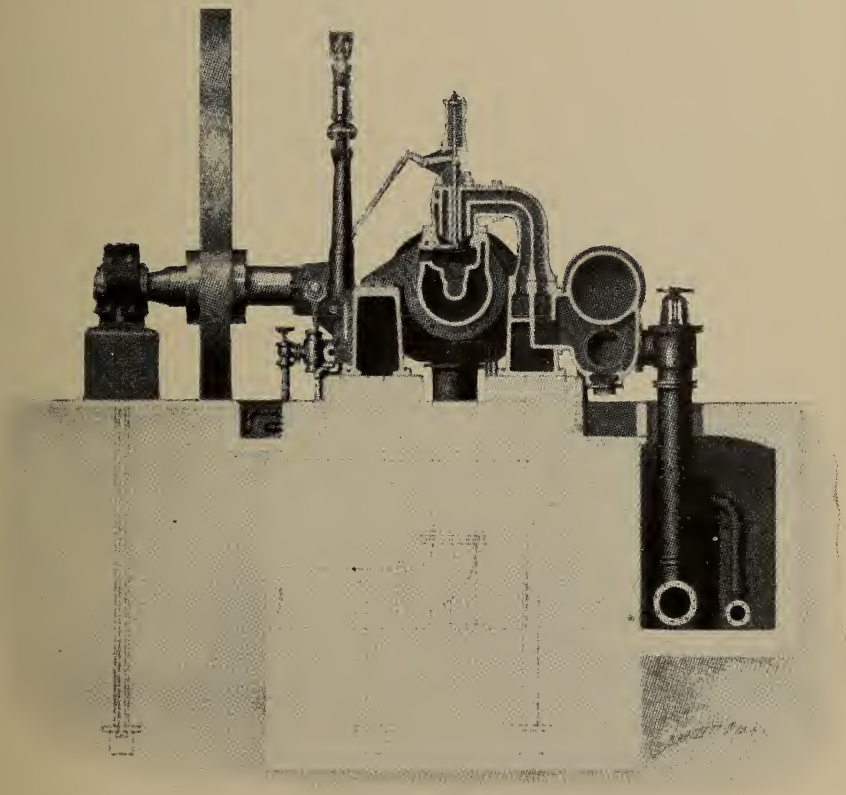


FIG. 6.—SECTION THROUGH SUCTION VALVE OF KOERTING ENGINE.

D, Assuming the displacement of the present steam blowing engines by gas driven ones, but still using blast furnace gas for heating the stoves.

We will take the following data from actual practice as an example for these calculations:

Air blast pressure.....10 lbs.
Daily output (24 hrs.).....98.57 tons
Gas analysis (by volume) combustible per cent. $\left\{\begin{matrix} CO = 24 \\ H = 2 \\ CH_4 = 2 \end{matrix}\right\} = 28\%$.
Inert per cent. $\left\{\begin{matrix} N = 60 \\ CO_2 = 12 \end{matrix}\right\}$.....72%
Ratio of CO to CO_2.....1 to 2
Fuel consumption per ton pig iron .....900 kilos
Temperature hot blast.....1022° F.
Assumed efficiency of hot blast stoves 65%

Calculation.

Thermal value of blast furnace gas in calories per cubic metre..953
Thermal equivalent of blast furnace gas per 100 kilos iron melted .....385012 calories
After deduction of 10% for uniform waste we have left.. 346511 calories
Weight of air blast in kilos, per 100 kilos pig iron.....388
Volume of blast in cubic metres per 100 kilos pig iron.....300
Thermal units absorbed by air blast .....60900 calories
Thermal units supplied to hot blast stoves at 65% efficiency.. 93,700 "
Thermal units left.....252,800 "
Assuming thermal efficiency of 25%, this gives.....4,100 I. H. P.

A.

Thermal units available.....346,511 calories
At 25% efficiency we have .....5,553 I. H. P.
Power required for blowing, etc.....460 I. H. P.

However, using blast furnace gases in boiler we can only count on about 5% efficiency, so we will require about $5 \times 460 = 2{,}300$ I. H. P., really leaving for other purposes $5{,}553 = 2{,}300 = 3{,}253$ I. H. P.

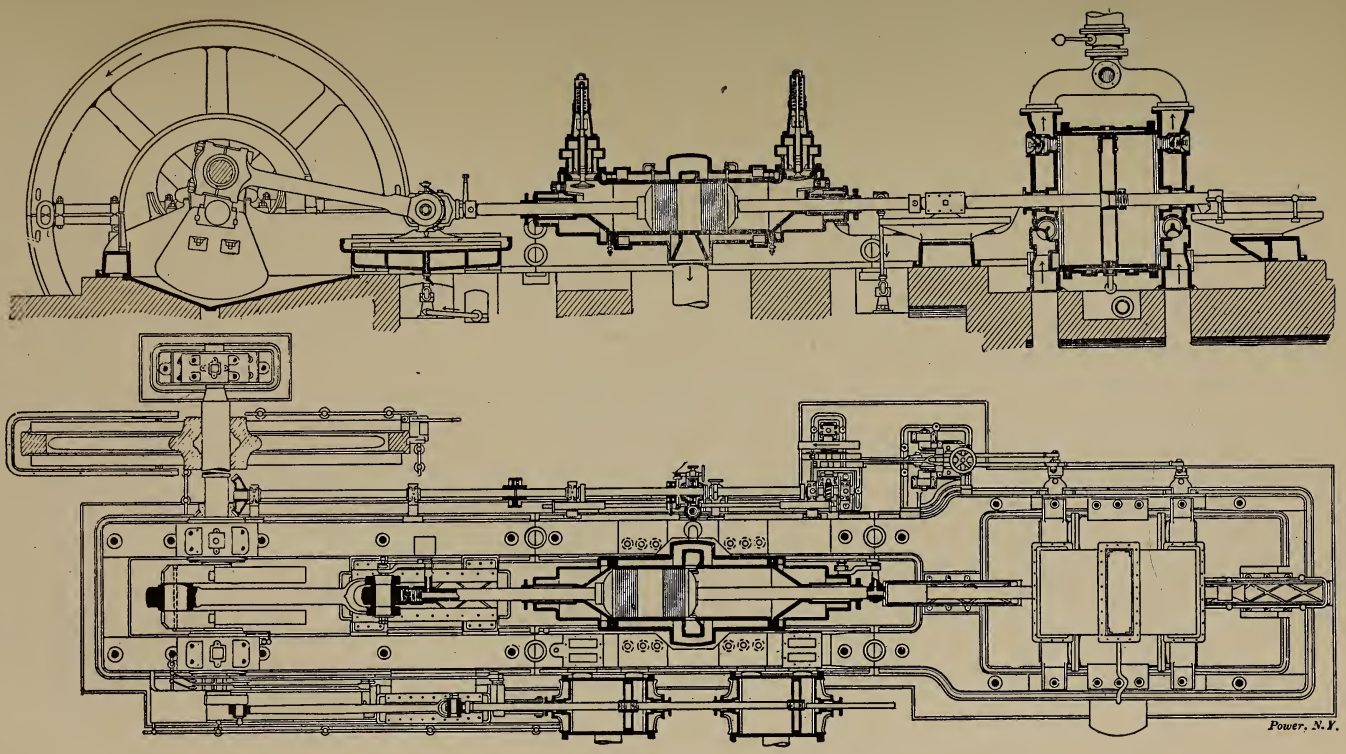


Fig. 7.—500 H. P. Koerting Gas Engine Coupled to Blower.

B.

I. H. P. available, 5,553; I. H. P. blowing, 460; assuming 25% efficiency; so we have left 5,553 — 460 = 5093 I. H. P.

C.

Assuming waste of gas in charging is reduced by $\frac{1}{2}$ we then have $\frac{38501}{2}$ = 19,255 calories @ 25% efficiency = 314 I. H. P.

So total I. H. P. available is 5,093 + 314 = 5407 I. H. P.

D.

Heat absorbed by stoves.....93,700 calories
Heat left .....252,810 "
I H. P. at 25% efficiency.....4,125
I. H. P. for blowing, etc.....460
I. H. P. left 4,125 —460 = 3,665 I. H. P.

These results show the advantages obtained by different uses of the gas.

Another calculation made by Mr. Campbell of the Pennsylvania Steel Co. gives a somewhat different result. His results are based on American practice where the ratio of CO_2 to CO is as low as 1:1.7 against 1:2 in the above calculation for European practice.

Taking a furnace making 300 tons pig iron per 24 hours we see by the table in a previous part of this paper, that the volume of gas varies from 2,921 to 6,144 cubic metres per ton iron, and the heat values corresponding vary from 2,150,000 calories to 5,026,000 calories, per ton pig iron. The calculations are based on the lowest of these results. Now in a furnace producing 300 tons per day about 19,700 cubic feet of air blast is used per minute, and this is to be heated to 1,300° F. or 700° C., and since 0.307 is the specific heat of air per cubic metre then the heat put into the blast is 172,670,000 calories per 24 hours.

Now the blast furnace gas enters the hot blast stoves at, say, 170° C., and has a specific heat of 0.320 calories per cubic metre, and if there are 355,000 cubic metres used to heat the blast as is usual in

furnaces of this size, we have entering the hot blast stove as sensible heat 355,000 × .320 × 170 = 19,312,000 calories. We must then supply by combustion 172,670,000 — 19,312,000 calories in 24 hrs. Assuming efficiency of stoves 52%, a rather low estimate, we must supply 292,165,000 calories or about one-third of the heating power of the gas. We have left then, of the 2,150,000 calories per ton pig iron, or 645,000,000 calories per day, about 28,000 I. H. P., assuming 100% efficiency. Assuming efficiency of boilers at 60%, and of the steam engines of 10% we get 1,700 H. P., and about 1,500 H. P. is used in the blowing engine, leaving 200 H. P.

Assuming that gas engines of only 15% efficiency are used we get 4,200 H. P., and so have left 4,200 — 1,500 = 2,700 H. P. As-

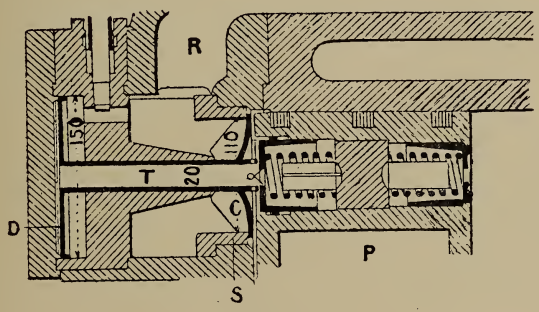


Fig. 8.

suming the gas engines have an efficiency on I. H. P. of 25%, a not unusual result as shown by a previous part of this paper, we have 7,000 I. H. P., leaving 7,000 — 1,500 = 5,500 I. H. P. after supplying the blowing engines. In no part of this latter calculation have high values been assumed, so that this result represents the power produced with the most economical furnace. Probably, however, the result of the previous calculation is too high and no doubt the ordinary conditions are represented by a result lying between the two.

At Thornby, England, in three furnaces producing 350 tons per day about 2,628,000 cubic feet of gas per hour is produced. About

half of this is used in the stoves and 239,000 cubic feet by boilers supplying gantry lift, etc., leaving 1,075,000 cubic feet. Taking the requirements of this gas at 130 cubic feet per H. P. this 1,075,000 cubic feet produced 8,269 H. P. The indicated horse power of blowing engines, etc., amounted to 1,388 H. P., leaving 6,881 H. P. for other purposes.

At Differdingen one ton pig iron gives 4,500 cubic metres of gas, 10% of which is lost, and 50% is used to heat the blast, leaving 2,000 cubic metres; the engines here use 29 cubic metres of gas per B. H. P. per hour, so that in the production of one ton of pig iron about 65 H. P. is produced.

The following tests were made at the Ormsby Iron Works, Middlesborough, England, to determine the relative efficiency of the gas engine against boilers fired by gas and steam engines.

Thermal Efficiency of Babcock and Wilcox Boiler.

Gas analysis (by volume):

$N = 56.61\%$	$CO_2 = 16.32\%$
$CO = 27.02\%$	$H = .055\%$

Calorific value 101.72 B. T. U.'s per cubic foot.

To determine the amount of gas used, its average velocity was calculated from the formula $V = \sqrt{\frac{2gh}{12}} \times 758 \times \left(1 + \frac{T - 32}{493}\right)$ was used the height "h" being measured by a Pitot tube and a Koenig differential gauge. In this case V = 46.6 feet per second, and the area of the pipe section was 2.88 square feet, so the quantity of gas per second was 134.20 cubic feet. This was at a temperature of 595° F., and amounted to 62.71 cubic feet at 32° F. or 225,756 cubic feet per hour at 32° F. The thermal units contained in this were 225,756 × 101.72 = 22,963,900 B. T. U.'s. The temperature of the feed water was 175° F., and it was evaporated into steam at 90 lbs. absolute pressure, so total heat in 1 lb. was 1,034 B. T. U.'s, and 12,000 lbs. were evaporated, so total heat given to water was 12,000 × 1,034 = 12,408,000 B. T. U.'s.

$$\text{Efficiency of boiler} = \frac{12{,}408{,}000}{22{,}963{,}900} = 54.03\%.$$

The efficiency of the engine was 12.46%, so combined efficiency of plant was 6.732%.

Efficiency of Gas Engine.

The Pitot tube and differential gauge were used on both air inlet and gas inlet, and pressures were: gas = 2.4 mm.; air = 1.2 mm.; the pressures remaining constant for several days. Now velocity varies as $\sqrt{\text{pressure}}$ so velocities were 1.414 to 1.

Gas analysis (volume):

N = 57.05%	CO_2 = 16.25%
CO = 26.66%	H = .084%

Calorific value of gas, 98 B. T. U.'s per cubic foot.

Gas consumed per minute calculated from volume of cylinder and proportions of gas and air was 38.44 cubic metres, or 2306.4 cubic feet. This was at 65° F., so at 32° the amount was 1272.014 cubic feet per minute. At 98 B. T. U.'s per cubic foot there were supplied to the engine $98 \times 1272.014 = 124{,}657$ B. T. U.'s per minute.

I. H. P. of engine was 742 so that its efficiency was 25.43%. Hence in this case the ratio of efficiency of gas and steam plants was 3.7 to 1.

It would be unnecessary here to give any further tests or calculations regarding the efficiency of these engines. To determine the amount of power which can be obtained for a given plant the data given in a previous table in this paper can be used and the results calculated as has been shown. It is, however, quite evident that the blast furnace gas engine will reduce the cost of steel production by a considerable amount, since all the power required to drive a complete steel plant can be obtained from the blast furnaces used to

produce the pig iron. In Europe, the high price of fuel has led to the introduction of the gas engine to a large extent, and, although it is only since 1899 that the gas engine began to be of practical use in this respect, it is now being introduced into the blast furnace plants all over the continent. In America blast furnace gas engines are almost entirely unknown, the only large plant being that of the Lackawanna Steel Co., which is at present being erected, although small engines are being used by the Maryland Steel Co., and the Pennsylvania Steel Co. There is no doubt, however, that the next few years will see these engines in general use.

TREASURER'S REPORT.

Toronto, March 25th, 1904.

MR. PRESIDENT:—

I beg to submit the following statement showing balances, receipts and expenditures for term ending March 25th, 1904.

To balance on hand March 27th, 1903			$ 365 99
" amount of members' fees	$251 25		
" " life members' fees	10 00		
" " Library proceeds	992 03		
" " advertising and sale of pamphlet No. 16	123 92		
" " advertising in pamphlet No. 17	3 00		
			1,380 20
			$1,746 19
By amount of publishing pamphlet No. 15	$355 50		
" " printing and binding account	161 31		
" " paper and supplies	652 33		
" " expenses of representatives to McGill, Queens' and Hamilton	42 00		
" " customs and express	37 77		
" " discounts	1 15		
" " election expenses	6 50		
" " postage and stationery	21 94		
" " die and pins	8 50		
" " W. J. Graham's annual fee	3 00		
" " Editor's salary and Pub. Com. com'n.	76 25		
" " assistant librarian's salary	25 00		
" " photo for Library	1 25		
			$1,392 50
By balance in Bank of Commerce			353 69
			$1,746 19

Notwithstanding the increased expenditures, it will be noticed that the Society has held its own fairly well during the past year.

The work of the Society has become so extensive that some of its officers have to be remunerated for their services, which the revenue from the increased number of students is not sufficient to offset.

We would suggest that every graduate become a life member, in this way supporting the work and aim of the Society, and maintaining it in the high position which it now holds among the Engineering Societies of the Continent.

All of which is respectfully submitted.

J. M. WILSON,
Treasurer.

AUDITORS' REPORT.

March 25th, 1904.

We have to-day audited the books of the Treasurer, Mr. J. M. Wilson, and have found them correct, and find a

Cash Balance of	$353 69
Outstanding Debts due Society	129 00
Total	$482 69
Liabilities of the Society	$136 71
Net Balance	$345 98

W. G. MCFARLANE,
D. E. O'BRIEN, } *Auditors.*

EXCHANGES.

Ontario Land Surveyors, Toronto, Report, 200 copies.
Michigan Engineering Society, Climax, Mich., Michigan Engineer, 135 copies.
Engineering Society, University of Illinois, Champaign, Ill., Technograph, 125 copies.
Association of Civil Engineers, Cornell University, Ithaca, N.Y., Transactions, 125 copies.
Engineering Society, University of Michigan, Ann Arbor, Michigan Technic, 125 copies.
Perdue Society of Civil Engineers, Lafayette, Ind., 100 copies.
Colorado School of Mines, Golden, Col., 100 copies.
Ontario Association of Architects, Toronto, Ont., 40 copies.
University of Toronto Studies, Toronto, Ont.
Ontario Historical Society, Education Dept., Toronto, Ont.
Bureau of Mines, Toronto, Ont.
Geological Survey of Canada, Ottawa, Ont.
Queen's University, Kingston, Ont.
Canadian Society of Civil Engineers, Montreal, P.Q.
Canadian Mining Institute, Nova Scotia, Can.
Association of Engineering Societies, Philadelphia, Pa.
Pratt Institute, Brooklyn, N.Y.
Rensellaer Society of Engineers, Troy, N.Y.
Columbia University, New York, N.Y.
American Society of Civil Engineers, New York, N.Y.
United States Coast and Geodetic Survey, Washington, D.C.
United States Tests of Metals, etc., Washington, D.C.
Patent Office, London, Eng.
Institution of Mechanical Engineers, London, Eng.
Royal Institution of British Architects, London, Eng.
Society of Chemical Industry, London, Eng.
Institution of Junior Engineers, London, Eng.
Institution of Engineers and Shipbuilders, Glasgow, Scotland.
Societé des Ingenieurs Civils de France, Paris, France.
Indiana Engineering Society, Indianapolis, Ind.

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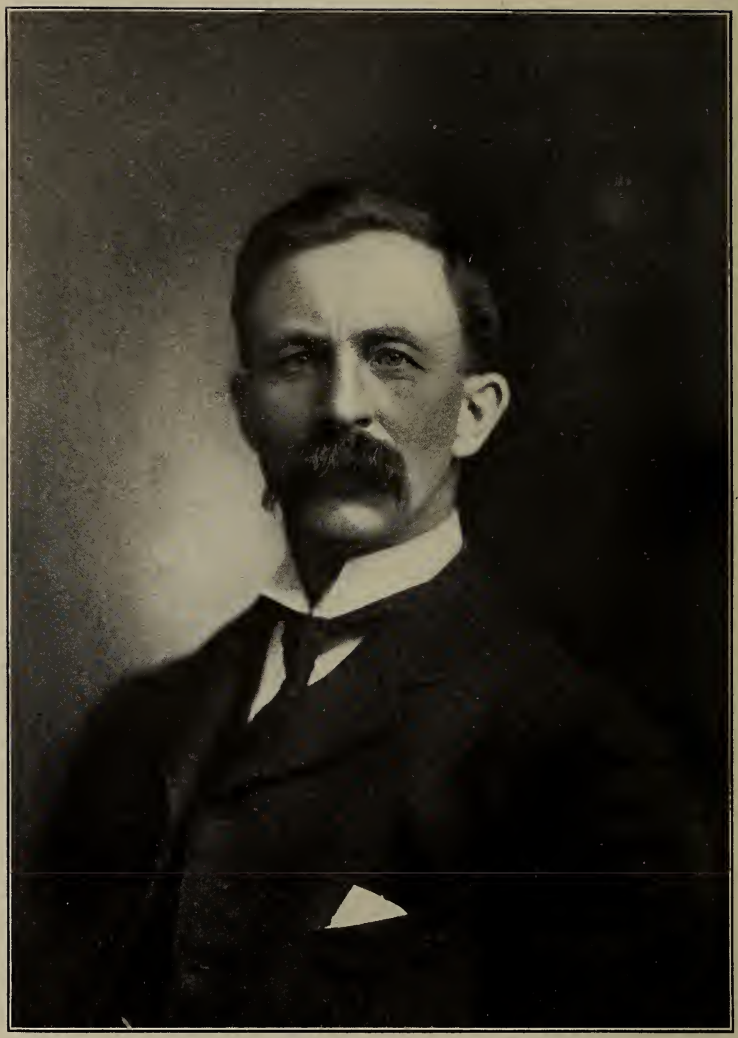

Louis B. Stewart

No. 18 1904-1905

TRANSACTIONS

OF THE

ENGINEERING SOCIETY

OF THE

School of Practical Science

TORONTO

PRICE - - 50 Cents

TORONTO:
THE CARSWELL COMPANY, LIMITED
1905

Entered according to the Act of the Parliament of Canada, in the year one thousand nine hundred and five, by the Engineering Society of the School of Practical Science, in the Office of the Minister of Agriculture.

PREFACE.

The eighteenth volume of the Transactions of the Engineering Society of the Ontario School of Practical Science is offered to our readers as a record of part of the work accomplished by the Society during the session 1904-1905.

The papers read before the Society were all instructive and interesting, and as usual the lantern slide was freely made use of in presenting them. A programme of the meetings of the year is printed on page xiv. Some of the papers read have been published in other periodicals and are not reproduced here.

We take pleasure in presenting our readers with a portrait of Professor L. B. Stewart, who was this year elected an honorary member of the Engineering Society.

The Society wishes to tender its hearty thanks to all who contributed.

Toronto, April 18, 1905.

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Charlebois, J. P. C., '05.
Chas[illegible], A. [illegible]., '05.
Clement, S. R. A., '05.
Corrigan, T. E., '05.
Crosby, N. L. R., '05.
Dowling, F., '05.
Ferguson, G. H., '05.
Fierheller, H. S., '05.
Harrison, F. W., '05.
Hendry, M. C., '05.
Henry, E. A., '05.
Hertzberg, C. S. L., '05.
Hewson, W. G., '05.
Jones, G. S., '05.
Kribs, G., '05.
Laing, P. A., '05.
Latornell, A., '05.
Leighton, J. W., '05.
Loudon, T. R., '05.
Lytle, F. H., '05.
McGorman, S. E., '05.
McGregor, W. W., '05.
McKenzie, D. W., '05.
McLean, C. A., '05.
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Mace, F. G., '05.
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Morden, L. W., '05.
Morton, P. E., '05.
Munro, G. R., '05.
Nicklin, W. G., '05.
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Porte, W. B., '05.
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Ramsey, G. L., '05.
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Richardson, W. L., '05.
Ross, R. B., '05.
Rothwell, T. E., '05.
Scott, G. S., '05.
Serson, H. V., '05.
Shirriff, C. S., '05.
Sisson, C. E., '05.
Southworth, H. S., '05.
Stewart, D. L. N., '05.
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Stubbs, W. F., '05.
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Swan, W. G., '05.
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Thomson, L. R., '05.
Tillson, E. D., '05.
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Treadgold, W. M., '05.
Turner, W. E., '05.
Uren, A. E., '05.
Vansittart, G. E., '05.
Vaughan, J., '05.
Wagner, H. L., '05.
Weddell, R. G., '05.
Wickett, W. E., '05.
Yeates, P. M., '05.
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Amos, W. L., '06.
Arens, A. H., '06.
Armer, J. C., '06.
Arnott, G. C., '06.
Baker, M. H., '06.
Banting, E. W., '06.
Barber, F., '06.
Bates, M., '06.
Beeman, J. J., '06.
Bellisle, J. P., '06.
Beynon, D. E.,' 06.
Bissett, G. W., '06.
Blackwood, W. C., '06.
Bourne, O. B., '06.
Brady, W. S., '06.
Brandon, H. E., '06.
Brian, M. E., '06.
Broadfoot, F. C., '06.
Brown, T. W., '06.
Bunnell, A. E. K., '06.
Byam, F. M., '06.
Cameron, A., '06.
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Smithrim, E. R., '07.
Snaith, W., '07.
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Spencer, A. G., '07.
Stalker, J. D. B., '07.
Stewart, G. S., '07.
Stiles, J. A., '07.
Stiver, J. L., '07.
Stuart, J. L. G., '07.
Summers, G. F., '07.
Sylvester, K. B., '07.
Thomson, O. R., '07.
Toms, C. G., '07.
Tye, H. W., '07.
VanNostrand, J., '07.
Walker, J. A., '07.
Web, C. E., '07.
Wedlake, R., '07.
Weir, R. P., '07.
White, W. R., '07.
Wilkes, E. D., '07.
Williams, D., '07.
Wilson, A. F., '07.
Wilson, F. F., '07.
Woods, M. H., '07.
Workman, G. R., '07.
Wright, J. V., '07.
Ziegler, O. E., '07.
Zinkan, W. E., '07.

L. B. STEWART, O.L.S., D.T.S.

Professor Louis B. Stewart, who by a resolution adopted on the 18th of January last, was elected an Honorary Member of the Engineering Society, is a native of Port Hope, at the public and High Schools of which town he received his education. On leaving school he was articled to his father, Mr. Geo. A. Stewart, as an Ontario Land Surveyor. He assisted in the sub-division survey in Manitoba, and afterwards in a general engineering and architectural practice in Toronto. In 1881 he was engaged on the location of the Canadian Pacific Railway between Toronto and Peterboro. In 1882 he was granted a commission as Ontario Land Surveyor, and shortly after as Dominion Land Surveyor. About this time he removed with his father to Winnipeg, where they were associated in a general engineering and surveying practice until 1886, when Mr. Stewart, senior, was appointed Superintendent of the Rocky Mountain Park at Banff. During the next year, young Stewart was employed by the Dominion Government in making a topographical survey of the park, and in 1887 he received his commission as Dominion Topographical Surveyor.

In 1888 he was appointed Lecturer on Surveying in the School of Practical Science. In 1903 he was promoted to the rank of Professor of Surveying, the chair which he now fills.

His academic duties occupy during the session all Professor Stewart's time, but during the summer months his energies seek vent in various activities.

The summers of 1892 and 1893 he spent, in company with Professor Coleman, in exploring a portion of the Rocky Mountain region in the neighbourhood of the source of the Athabasca River and Mount Brown.

Mr. Stewart was in his youth a famous oarsman, who had been chosen by his club, the Argonaut Rowing Club, to represent them at the Henley Regatta. In 1893 when the object of the exploration had been attained he returned alone, in a canvas boat, by way of the Saskatchewan to Edmonton, a distance of about 400 miles.

In 1899 he went to Dawson and was engaged during the summer in a general surveying practice.

All who know Professor Stewart feel that the compliment paid him by the Engineering Society is no empty one, but a genuine expression on the part of his pupils, past and present, of their appreciation of his thorough knowledge of his profession, his painstaking and conscientious teaching, and his sterling character.

PROGRAMMES OF REGULAR MEETINGS, 1904-5.

Oct. 12th, 1904—

Short addresses on the following subjects:

Bridge Building, by C. R. Young.

Calumet and Hecla Mines, by C. G. Williams.

Testing Department of the Canadian General Electric Co., by C. E. Sisson.

The Toronto-Niagara Power Line, by W. Maclachlan.

Oct. 26th, 1904—

Factor of Safety for Concrete Dams, by John S. Fielding, C.E.

D. L. Raymond and F. Connery elected representatives to Varsity Board.

L. D. McKellar elected first year representative on Engineering Society Executive.

Nov. 9th, 1904—

Transition Curves. P. Gillespie, B.A.Sc.

The Application of Descriptive Geometry to Structural Steel Work. C. R. Young.

Dec. 7th, 1904 —

Raven Lake Cement Works. A. M. Campbell.

Western Cement Works. John McFarlane, B.A.Sc.

Jan. 18th, 1905—

The Relation of Forestry to Engineering. Dr. J. Clarke.

Mr. L. B. Stewart. D.T.S., was elected honorary member of the Society. The motion bringing Mr. Stewart's name before the Society was moved by F. N. Rutherford and seconded by B. Patten.

Feb. 1st, 1905—

The Power Plants of the Niagara District. C. B. Smith, M. Can. Soc. C.E.

Feb. 15th, 1905—

Concrete Cribwork. A. E. Gibson, B.A.Sc.

Winning of Aluminum. Jas. Horton.

March 1st, 1905—

The Dinner given by Our Old Boys in Pittsburg. Dr. W. H. Ellis.

The Non-Metallic Minerals of Canada. J. J. Bell, M.A.

March 15th, 1905—

Modern Machines. R. W. Angus, B.A.Sc.

A. T. Laing, B.A.Sc., and Wm. Barber, '05, elected Auditors for 1904-5.

March 28th, 1905—

The President's Address.

Nominations.

March 31st, 1905—

Reports.

Elections.

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ENGINEERING SOCIETY

OF

The School of Practical Science

TORONTO.

PRESIDENT'S ADDRESS.

GENTLEMEN:—

Before handing over to my successor the direction of the affairs of the Society, I must thank you for the honour you did me a year ago in electing me to the highest position in your gift, and also for the cordial and sympathetic support given during the year.

The finances are in an excellent condition, and steps have been taken to ensure a more complete system of book-keeping. The auditor's and treasurer's reports will be published in full.

The eighteenth volume of the Transactions of the Engineering Society is in press, and a few changes in its usual contents will be noticed. A new index has been prepared, the programmes of the regular meetings are given, a short account of the sixteenth annual banquet is published, and for the first time, the transactions appear under a suitable cover.

The time has arrived when some change should be made in the management of the Society. Within three years the sale of supplies

has trebled, and the work of the President has increased until it has become hardly reasonable to ask a student to accept the position.

Whether the interests of the Society will best be served by electing a Second Vice-President to be chairman of the publication committee, while allowing the First Vice-President to secure papers for the regular meetings, or by the appointment of a permanent secretary, is a question for others to decide.

Wishing you a prosperous year, I beg to present your President for 1905-6, Mr. Charlebois.

E. A. JAMES.

ESTIMATING STRUCTURAL WORK AND BRIDGES.

H. G. Tyrrell, '86.
Chief Engineer The Brackett Bridge Co., Cincinnati, Ohio.

The term structural work is very comprehensive. It includes all that class of buildings commonly known as steel cage construction, such as tall office buildings, stores, warehouses, apartment houses, and hotels. It includes also steel mill buildings and a great variety of semi-steel construction, such as ordinary business blocks, and public buildings which have a partial steel frame—stand pipes, water towers, floors, platforms, observation stands, and in short, all sorts of plate and bar construction ordinarily made at the shops of bridge and structural works are likewise included.

In these notes on estimating, questions of design cannot be considered to any great extent, and are touched upon only when inseparable from the estimate.

STEEL CAGES—COLUMN SPACING.

As the weight of steel in this class of buildings is principally in the floors, it follows that the greater number of tiers of column (within reasonable limits) the less will be the total weight of steel. Roughly speaking, about three-quarters of all the steel is in the floors, and the remaining one-fourth in the columns.

Hotels and office buildings, with frequent partitions, will allow of reasonably close spacing for the columns. It is of course desirable to keep the columns inside the partitions, or elsewhere out of sight as far as possible. On the other hand, stores or public halls will admit of only the fewest possible number of columns, or possibly none at all in sight. It frequently occurs that halls or office buildings have stores in the lower story, and then the tiers of columns in the upper stories must be carried on a frame of heavy girders at the second floor level. In other cases office buildings have been designed with very few tiers of columns, so that partition may be changed or removed to suit

the tenants, leaving a clear and unobstructed floor area. Warehouses for the storage of ordinary goods can usually have columns spaced fairly close together, say 12 to 16 feet apart. And so it will be seen before the position of these is fixed there will be many considerations. In designing the principal cross beams it is sometimes economical to use the cantilever principle, and splice these beams at the points of contra flexure. In the case of a 12-story apartment house recently designed by the writer, where the rooms were mostly quite small, it was possible to space the columns not over 10 feet apart, and still keep them inside the partitions. This of course gave a very light frame, the weight of which, including both floors and columns, and complete frame for the outside walls, was only 14 pounds per square foot of floor area. Another similar building 11 stories high, in which the columns were spaced 25 feet apart, weighed 28 pounds per square foot of floor area. This last building was for office use and was proportioned for heavier floor loads than the hotel, but the principal reason for the greater weight of steel was the wider column spacing. It too had a complete steel frame in the outside walls.

Buildings of different kinds designed according to the building law of the city of Boston, not over 11 stories high, and with columns spaced about 15 feet apart, have steel frames weighing about as follows:

Apartment houses and hotels, with outside frames, 14 pounds per square foot.

Apartment houses and hotels, without outside frames, 9 pounds per square foot.

Office buildings, with outside frames, 23 pounds per square foot.

Office buildings without outside frames, 15 pounds per square ft.

Warehouses, with outside frames, 28 pounds per square foot.

Warehouses, without outside frames, 18 pounds per square foot.

From the above a rough approximate estimate of the weight of steel in any proposed new buildings may very quickly be made. For buildings higher than 11 stories—the greatest allowed by the Boston law—the weight of floors will increase in direct proportion to the number of stories, while the weight of columns will increase more rapidly.

Whether to build the outside walls of solid brick, or to use a steel frame with a thin brick wall merely as a curtain, will depend on the following considerations. First, which method in itself, apart from any considerations of available floor space, is the cheaper, and second, in case the steel frame and curtain wall be more expensive, will the increased floor space secured by the use of thinner walls make up for the extra cost of construction? This second consideration will occur only when the area of the lot is limited, and land values high. If additional land could be secured at a reasonable price, the question of increasing floor space by decreasing the thickness of the walls, would not be considered.

The following table, giving the weight of cast iron column bases, is new, and will be useful when estimating the steel in tall buildings:

Size of square base.	Weight.	Size of square base.	Weight.
22 x 22	600 lbs.	32 x 32	1340 lbs.
24 x 24	750 lbs.	34 x 34	1450 lbs.
26 x 26	880 lbs.	36 x 36	1600 lbs.
28 x 28	1020 lbs.	38 x 38	1700 lbs.
30 x 30	1180 lbs.	40 x 40	1850 lbs.

The practice of designing columns in the lower stories, to carry only a portion of the sum of all the maximum floor load above, is reasonable, and is allowed by the building laws of some of our cities. It is not allowed by the building department of the city of Boston. According to the percentages allowed by the New York building law, the saving in the columns amounts to about 10 per cent. This will be from 2 to 3 per cent. of the entire weight of steel in the building.

SPACING OF BEAMS.

The spacing of floor joist will depend very largely on the kind of fireproofing to be used. Most of the concrete systems can use spacing up to 8 feet, while for terra cotta blocks it should not exceed about 5 feet. Many architects use this latter spacing so that it can be used for any system. It is economical of steel to use wide spacing with deeper beams. The thickness of floor may, however, be limited, in which case it becomes necessary to use a shallower beam and smaller spacing.

As the fireproof companies do not advertise their prices, nor even give list prices, but sell on the principle of get all you can, it will be well for the architect or engineer to make several different arrangements of beams for a typical floor, and secure prices on the fireproofing for all these designs. He can then combine the costs of steel and fireproofing and select the cheapest arrangement. He may at the same time receive prices for fireproofing one tier of inside columns, to assist him in deciding on the best arrangement of columns.

In buildings with an outside steel frame, it may be noted that wall girders spaced two or three stories apart, will frequently be satisfactory, and give a much less weight than if provided at every story. Another common practice is to provide outside columns to carry the floor loads only, making the wall of sufficient thickness to be self-supporting. In this case, as also in the case of outside walls, without any columns, it will be necessary to provide a supporting channel against the wall to carry the floor. Some of the fireproof companies prefer to use a continuous flat plate built into the brick work, and projecting about 2 inches, to support the floor. Others use a brick corbel instead.

MILL BUILDINGS.

For a full description of the best practice in designing and estimating this class of buildings, the reader is referred to a book entitled "Steel Mill Building Construction," written by the author of this article, and published in New York.

SEMI-STEEL BUILDINGS.

Nearly all large business blocks and public buildings contain more or less iron and steel in the way of beams, columns, wall plate anchors, and the like. It is frequently the custom to make the principal floor beams of steel, and all others, including joists, of wood. In such cases the parts must all be proportioned to carry safely their maximum loads, or in large cities to conform to the building law.

OFFICE METHODS.

In order to have a systematic way of recording all the principal data in connection with any building, the following blank heading will be found convenient for estimate sheets:

SIZE AND SECTION SHEET.

Buildings. ..... *190* **Estimate No.** .....

Name ..... *Sheet* ..... *of* .....

Size ..... *Area* ..... *Height* ..... *No. Stories* .....

No. Pieces ..... *span clear* ..... *eff* ..... *extreme* .....

Purlins ..... *Rafters* ..... *Monitor* .....

Distance between Trusses ..... *Pitch* ..... *Covering* .....

Live Load per sq. ft. .....

Dead " " " .....

Specification ..... *Tension* ..... } *Material* .....

..... *Compression* ..... } .....

Estimated by ..... *Drawing by* .....

The whole sheets may be ordinary cap size, 8 x 13 inches, and the paper should be cross ruled, in 1-8 inch squares. In order to take blue prints from the estimates, the paper should be a thin strong linen. On this paper the design may be studied out to a small scale. For studies of this kind, large sheets or large scales are not suitable, as the attention is not so easily concentrated when sketches are spread over a larger area. And here it may be stated that office tables and reference sheets generally should be made of small size, to be of the greatest use. A reference sheet 6 x 8, or 8 x 10, that can be easily handled, will be used where a larger one would not.

After the general design has been studied out on a small scale line diagram, a cross section should be made to 1-4 or 1-8 inch scale, to show general details. These and all stress sheets should be carefully made with india ink. All the principal operations connected with the calculations should be preserved for reference. Multiplication may be done on scrap paper. Fill in all principal dimensions in ink.

After the design has been made, the successful estimator will go over it again the second time, to see where it can be improved. He will take out here, and put in there, add extra bracing where it may be necessary, and reduce the weight where his judgment will allow it. He will probably keep his original design up to the full capacity that the buyer has called for, and then figure out what deductions can be made, if the capacity of certain parts be decreased. It is often the case, for example, that an owner thinks he will require a building to carry a 50-ton crane, but when the cost is considered, he is willing to use a crane of 30 or 40 tons instead. All such propositions as this will interest a prospective buyer, and will greatly add to the engineer's chances of securing the work. If the estimate is made on a design submitted by the buyer, it may be that an alternate design and estimate would be attractive.

BRIDGES.

For use in estimating bridges, the following headings for estimate sheets will be found convenient. One is for railroad, and the other for highway bridges. The data on which the design is based can be filled in for each separate case.

SIZE AND SECTION SHEET.

Railroad Bridges. ..... 1 .... **Estimate No.** .....

Name ..... *Sheet* ..... *of* .....

Spans ..... *clear length* ..... *eff* ..... *extreme* .....

No. Tracks ..... *No. Trusses* ..... *Distance c. to c. Trusses* ..... *Depth* ..... *ft.*

Panels .....

Flooring .....

Live Load .....

Live load per foot of Bridge ..... *lbs.* *Dead load per foot of Bridge* .....

" " " *Truss* ..... " " " *Truss* .....

" " *panel per* " ..... " *Tension* ..... } *Material*

Dead load " " ..... " *Compression* ..... } .....

Specifications .....

Estimate by ..... *Drawing by* .....

SIZE AND SECTION SHEET.

Highway Bridges. ..... *190*.... **Estimate No**.....

Name..... *Sheet*.....*of*.....

No. Spans.....*clear length*.....*eff*.....*extreme* .....*Depth*.....*ft.*

Roadway.....*ft*..... *Walks*.....*ft*..... *Panels each*.....*Joists*.....

Distance c. to c. Trusses.....

Flooring ..... *Fence*.....*Covering of Sides*.....*Windows*.....

Live Load.....*pounds square foot of roadway,*.....*pounds square foot of walks*

Concentrated load.....

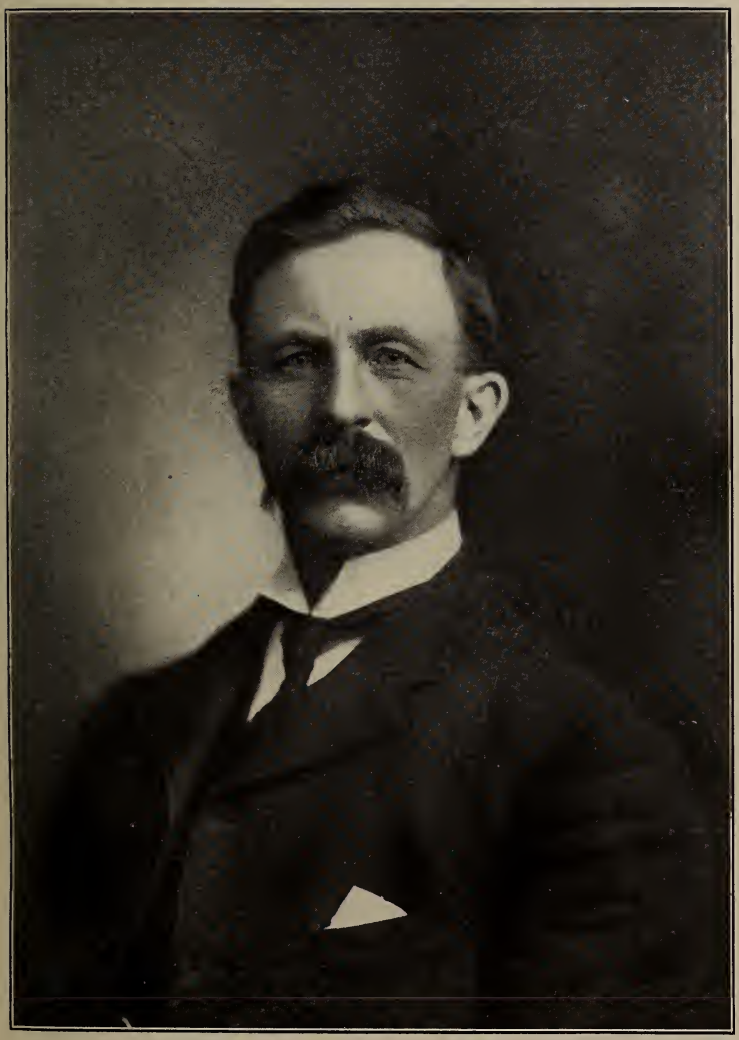
Live load per foot of Bridge.....*lbs.* *Dead load per foot of Bridge*.....*lbs.*

" " " *Truss*..... " " " " *Truss* ..... "

" " *panel per Truss*..... " *Tension* ..... } *Material*

Dead " " "..... " *Compression* ..... } .....

Estimate by..... *Drawing by* .....



Louis B. Stewart

When making the preliminary estimate to determine the economic number of spans for a proposed new bridge, or as a check on final quantities, after the design has been made, and the weight figured, the following original formulæ will be found necessary and reliable:

ORIGINAL FORMULÆ FOR THE WEIGHT OF BRIDGES.

By H. G. Tyrrell, Civil Engineer, Boston, Mass.

Railroad Bridges.

All weights are per lineal foot of single track bridge. Steel only.

Live loads, two engines, 100 tons each, and 4,000 lbs. per lineal foot of track, units 10,000 lbs. and 12,000 lbs. per square inch.

Deck plate girder bridge	$100 + 9$
Deck lattice girder bridge	$100 + 8$
Half through plate girder bridge	$300 + 12$
Half through plate girder bridge, ties on shelf angle	$200 + 8\frac{1}{2}$
Half through plate girder bridge, with solid steel floor	$600 + 10$
Riveted through truss bridge	$400 + 6$
Riveted deck truss bridge, ties on top chord	$200 + 7$
Through pin bridge	$400 + 5\frac{1}{2}$
Deck pin bridge with stringers	$400 + 6$
Deck pin bridge, ties of top chord	$300 + 6$

Railroad Trestles.

Loads as above.

Weight of spans as above.

Weight bents and bracing, 9 lbs. per square foot of side profile, from ground to base of rail.

Electric Railroad Bridges.

To carry 25-ton cars, or 2,000 lbs. per lineal foot of track, units 10,000 lbs. and 12,000 lbs. per square inch.

Weight of steel per lineal foot of single track bridge, are for

Beam bridges	$50 + 5$
Deck plate girder bridges	$50 + 4\frac{1}{2}$
Pony truss bridges	$250 + 1.5$
Through truss bridges	$250 + 1.3$

Electric Railroad Trestles.

Weight of spans as above.

Weight bents and bracing = 6 lbs. per square foot on side profile, from ground to base of rail.

Highway Bridges, with Wood Floors.

Dead weight of floor = 40 lbs. per square foot. Live loads, 100 lbs. per square foot, and units 10,000 lbs. and 12,000 lbs. per square inch.

Weights are per square foot of floor, and include steel only, without joists.

Girder bridge, with sidewalks ..... $3 + \frac{1}{4.4}$
Girder bridge, without sidewalks ..... $3 + \frac{1}{3.4}$
Truss bridge, with sidewalks ..... $3 + \frac{1}{8}$
Truss bridge, without sidewalks ..... $5 + \frac{1}{7}$

Highway Bridges, with Solid Floors.

Dead weight of floor = 150 lbs. per square foot.

Deck-plate girder bridges ..... $3 + \frac{1}{5}$
Half through bridges ..... $3 + \frac{1}{2.4}$
Truss bridge ..... $3 + \frac{1}{4}$

In the above I represents the length of span in feet, centre to centre of bearings.

These formulæ apply to ordinary types of American bridges, but do not include long spans or unusual forms. To obtain approximate estimates for cantilevers, arches, or suspension bridges, reference may be made to tables of these which the experienced estimator will have at hand. And while we prize originality in design, at the same time it must be acknowledged that most of our bridges are copies or modifications of something that has been built before. The same is true in reference to architecture and building. In planning a new building, the architect will assemble a number of features that have been used on various other buildings, some of them perhaps for ages, and work them into his new design. As a whole the completed design may not be a copy of any previous construction, but its parts have been repeatedly used elsewhere.

Even the cantilever, which is the nearest to a new conception in bridge design, is a principle new in application only. In a rude form cantilever bridges have long been in existence.

In calculating stresses for moving concentrated loads, it is much easier and quite as reliable to use the equivalent uniform load. Or if the weight of different engines varies uniformly, and the wheel spacing is the same for all engines, then if the shears and moments be found for one case, for other engines the shears and moments will vary in direct proportion to the weight of engine. This is the system used in Cooper's Revised Railroad Specifications. For other miscellaneous engines the estimator may already have cards figured, and if he has not, he can readily make them.

CALCULATIONS.

There is much time and energy wasted in useless refinement in the design of ordinary steel structures. By many mathematics is thought to be the height of engineering, while in reality it is but an assistant to judgment. Arbitrary loadings are assumed which in many cases are not realized within 50 per cent. or more, and from these assumptions the calculations are carried out to decimals. The following extract in this connection is taken from the preface of Trautwine's Engineer's Handbook: "Comparatively few engineers are good mathematicians, and in the writer's opinion it is fortunate that such is the case, for nature rarely combines high mathematical talent with that practical tact and observation of outward things so essential to a successful engineer. There have been it is true brilliant exceptions, but they are very rare. But few even of those who have been tolerable mathematicians when young can, as they advance in years and become engaged in business, spare the time necessary for retaining such accomplishments. Let the savants work out the results, and give them to engineers in intelligible language. We can afford to take their word for it, because such things are their specialty."

The president of a large bridge manufacturing company used to say that "he would rather have a good guesser than a mathematician any day." In other words, the judgment of one who has had experience is more to be depended upon than the conclusions of an inexperienced mathematician.

In figuring stresses in ordinary trusses, it will save much time to use truss co-efficients such as are published in several of the mill hand books. Or if these do not suit the form of truss, new co-efficients may very easily be determined. All such co-efficients should be preserved for future use.

Where there are several figures to be multiplied or divided by the same number, it will save much time to use a slide rule or calculating machine. In other cases figuring can be done as easily and quickly in the ordinary way. It is a saving of time, with less liability to error, to perform all similar calculations on the various truss members consecutively. For example, find first all the shears, then all the moments, then all the inclined web stresses, then all the chord stresses, then all the required tension areas, then all the required compression areas, and so on without waiting to finish the consideration of any one piece.

The estimator will no doubt have at hand curves giving the weight of trusses for a great variety of loadings. To find the weight of a truss intermediate between those for which we have weight curves it will be close enough for approximate estimates to interpolate. Care must be taken, however, to see that the loads are of the same general class. For example, we cannot interpolate between weights of bridges for electric railways, that are figured for uniform live loads, and bridges for locomotives. The heavy wheel loads in the latter case require a much heavier floor system than for electric car service.

When bids are asked on a design furnished by the owner, it will sometimes be an advantage to submit also a price on an alternate design. For example, some shops can turn out riveted work much cheaper than pin-connected trusses. If then a price is asked for a pin-connected truss, it will doubtless interest the buyer to receive a lower price on one of riveted construction.

GENERAL DRAWINGS.

After the general design has been carefully studied out it is necessary to prepare a small scale drawing, that the buyer may see the general style of construction. This drawing is necessary principally when the buyer is not familiar with steel construction. Great care

should be taken in the preparation of general drawings and picture plans, to have them neat and attractive. For even though a design be carefully studied out, and contain real merit, if it be accompanied with a carelessly made picture plan, it may be passed by, and the more attractive plan be accepted instead.

TAKING OFF THE QUANTITIES.

Having completed our design, the next step is to figure off the quantities. From tables and formulæ for the weight of similar structures, an approximate estimate may be made in a few minutes. This will serve not only to give a rough idea of the weight and cost, but also as a check on final results. When the actual weight has been calculated the engineer should analyze the result, by reducing the result to pounds per square foot or lineal foot, and retain the results for use in estimating similar structures.

A convenient ruling for paper on which to figure quantities is given below. The various kinds of material may be kept in separate columns. Or if it is all beam work, these may be divided according to the following classification:

Beams punched in either web or flange.
Beams punched in both web and flange.
Beams coped or framed.
Double beams bolted together with separators.
Plain beams not punched.

ESTIMATE SHEET

....*190*

Name..... **Estimate No.**.....

Sheet.....*of*.....

No. of Pieces	DESCRIPTION	Weight Per Ft.	

Beams fittings such as separators, bolts and connections, should be kept separate, as a special price is charged for them. At present prices, an extra is charged for beams 18 inches deep and over, so these also must be kept separate from beams 15 inches deep and smaller. Where only a rough estimate is required without all this classification, it will be convenient to use one column for each different weight per foot, and write down only the total number of lineal feet, when figuring off the beams. For example, in place of writing down 2 — I beams 15 inch, at 42 pounds per foot, x 24 feet long, simply write the total number of lineal feet — 48 —, in the 42-pound column.

It is easier to figure off only one piece, or if the section be symmetrical like a Fink roof truss, then figure off only half. Then in summarizing the quantities, the total number of pieces may be put down.

The following formula gives a useful check on the weight of Fink roof trusses to carry the usual 40 pound roof load:

W = weight of steel per square foot of area covered.

L = length of span inside of walls.

D = distance centre to centre of trusses.

$$\text{Then} \quad W = \frac{12}{D} + \frac{L}{20}$$

CHECK LISTS.

In order to be sure that all items have been included in the estimate, it is convenient to keep at hand for reference, two check lists, one for buildings, the other for bridges. Then, before making the summary, these lists may be glanced over, to remind us of the various items frequently used in buildings and bridges, and if any have been omitted, they may then be included.

Bridges.

End Posts, Top Chords, Intermediate Posts, Shoes, Bed Plates, Floor Beams, Stringers, Stringer Shoes, Stringer Bracing, Bottom Struts, Shoe Struts, Portals, Top Struts, Knee Braces, Portal Brackets, Sway Struts, Sway Frames, Sidewalk Brackets, Fence, Fence

Braces, Sidewalk Braces, Bottom Chords, Diagonals, Suspenders, Counters, Laterals, Sway Rods, Portal Rods, Pins, Rollers, Pin Pilots.

Bolts: Lateral, Sway, Anchor, Floor, Erection, Hub Guard, Track.

Washers: Floor Bolt, Scaffold.

Lag Screws, Rivets, Nails and Spikes, Sheet Lead, Cast Raisers, Lateral Washers, Sway Washers, Name Plates, Newel Posts, Ornaments, Name Plate Fasteners.

Lumber: Ties, Guard Rails, Hub Guards, Joists, Floor Plank, Spiking Pieces.

Paint.

Erection Equipment: Tools, Coal, Forge, Crabs, Blocks, Ropes.

Buildings.

Trusses: Rafters, Lower Chords, Ties, Struts, Suspenders.

Knee Braces.

Ventilators: Trusses, Braces, Frames, Circular.

Columns: Main, End, Crane, Clearstory, Lean to.

Purlins: Roof, Side, End, Gable.

Finish Angles.

Struts: Rafter, Bottom Chord, Eave, Sway, Crane.

Girders: Plate or Lattice, Crane.

Brackets.

Floor: Beams, Joist, Plates.

Wall Plates, Bed Plates, Separators.

Rods: Tie, Longitudinal Ties, Sag Ties, Sways, Lateral.

Crane Rods, Anchor Bolts, Pins, Cotters, Bolts, Rivets, Stairs, Railing, Crane Track, Sheet Metal Work, Corrugated Iron, Ridge Capping, Flashing, Clips, Sheeting Rivets, Gutters and Down Spouts, Louvres, Wood Work, Windows, Doors, Door Frames, Name Plates, Paint.

COST OF ESTIMATING AND THE TIME REQUIRED.

The time required to make an approximate estimate of any ordinary structure need not exceed a very few minutes, as the weight can be taken directly from curves or figured out from formulæ. A design

and estimate with sizes and stresses for an ordinary bridge not exceeding about 200 ft. in length, can be figured out in from four to eight hours. Skew bridges require about 50 per cent. more time than square ones.

In taking off quantities and figuring up the weight of steel cage construction, a man can figure up about 300 tons per day. Therefore if a proposed new building is to contain, say 1,500 tons of steel, it can be taken off and estimated by one man in about five days.

Mill buildings and other light construction will require very much more time. An engineer who is continuously employed at designing and estimating bridge and building work, will probably estimate on from 10,000 to 15,000 tons of steel per year. Before the combination of the bridge companies occurred, the independent companies secured contracts for from 10 to 20 per cent. of all that they estimated. A good estimator would then expect to find from 1,000 to 3,000 tons of steel contracts coming in per year as a result of his labor.

LISTING OF MISCELLANEOUS ITEMS.

It is frequently necessary to include in the steel contract, such material as bridge plank, paving, doors and windows, for buildings, and occasionally the entire mason and carpenter work. It has been the custom to place the contract for the entire building with the one whose share is the largest of the whole. Therefore in the case of certain steel frame buildings, where the steel is the largest single item of the entire cost, the engineer will need to include all the various kinds of material. If there is any very large amount of other work, it is better for him to secure sub-bids from masons and carpenters for it, but if there be but little, it will be close enough to use his own figures. Windows should be given in outside dimensions, stating if sash are hung or fixed. The number and size of lights are also necessary. In the case of sash without frames, give the total number of such sash, with the size and number of lights in each. Windows in the side of monitors are operated either by chords, or shafts and gears from the floor. Gutters and conductors are listed by the number of lineal feet; roofing by the number of squares of 10 ft. x 10 ft.;

paving by the square yard; railing by the number of lineal feet, giving also the weight per foot; lumber by the number of feet board measure, keeping the different kinds of lumber separate.

Wall anchors securing floor joist to masonry are spaced about 10 ft. apart, and wall plate anchors, say 5 ft. apart.

The number and size of other masons' and carpenters' anchors are altogether too uncertain to classify, and where this item is important should be figured only from a schedule. But where these come in as a minor item with other work, the experienced estimator will include a lump sum to cover them.

FINAL CLASSIFICATION.

In all operations it is well to adopt uniform methods as far as possible. Therefore in making the final classification, it is well to have a blank form such as is given below. One of these may be filled out for each separate estimate. It will be seen that the cost of stock is first considered. Each kind is figured by itself at the current market price per pound. The cost of drawings and templets is then figured at a certain price per sheet. Next the cost of shop labor is considered, by giving the number of pounds of trusses, girders, columns, castings, beams, machined work, etc., each being figured at its own price per pound. Miscellaneous items that must be bought from other makers, are figured in by themselves, and then the total number of gallons of paint at so much per gallon. Then comes the cost of transportation, including freight, teaming, railroad fares for erection crew, and finally the cost of erection labor. By separating all the items in this way, a very close estimate is secured. It must however be noted that it is most of all important to have all the items in. The difference in the cost by omitting say a few beams, will often be much greater than if the entire classification were disregarded and the whole figured up at a round price per pound. If there is any doubt about certain items, then they may be figured separate from the rest.

Finally the engineer should state definitely on his estimate summary sheet just what items are included, and what are not. These should all be specified so the buyer may know exactly what is and what is not covered by the price.

SUMMARY SHEET

.....190.....

NAME..... ESTIMATE NO.....

Sheet.....of.....

	MATERIALS	QUANTITIES	
STOCK	*Plate, sheared*		
	" *rolled edge*		
	Bar, common		
	" *refined*		
	Angles		
	Rivets		
	Bolts		
	Pins and Rollers		
	Beams, 24″		
	" 20″		
	" 15″ *and under*		
	Z Bars		
	T's		
	Eye Bars		
	Cast Iron		
	Steel Joist		
LABOR	*Drawings*		
	Templates		
	Trusses		
	Girders		
	Columns		
	Bracing		
	Fence		
	Beams, coped or framed		
	" *punched*		
	" *plain*		
	" *with separators*		
	Machined Work		
	Cast Shoes, etc.		
	Steel Joists		

SUMMARY SHEET—*Continued.*

	MATERIALS	QUANTITIES	
MISCEL.	*Paint, 1st coat*		
	Fence		
	" *Posts*		
	Lumber		
	Spikes		
ERECTION	*Steel*		
	" *Joists*		
	Paint, 2d coat		
	Lumber		
	" *Joists*		
	" *Staging*		
	Bolts "		
	Fence		

PREPARATION OF ESTIMATE FOR DRAFTING ROOM.

As soon as a contract has been secured, if it be on his own design, the engineer should again go over his figures, and see not only that these are correct, but also that the design is plainly illustrated, and all his papers distinct and clear. After a lapse of several days, he may see some places where the design can be improved, or the work cheapened. The picture drawing should be made to correspond to the revised strain sheets. All A-1 notes or instructions that have been received verbally or otherwise should be written down on sheets

accompanying the estimate. Many minor requirements can more easily be described than illustrated. Instructions in reference to shipping, when the material will be required, and which part first, whom to see or correspond with for further information, color and number of coats of paint, etc., should all be written down. The contract may or may not be for all items in the estimate, so it should be clearly stated what the contract does include. Then, when all data and papers in connection with the work have been collected, these should be blue printed for the drawing office, and the originals kept on file for record.

THE NON-METALLIC MINERALS OF CANADA.

J. J. Bell, M.A.

Within the recollection of many still living, the only minerals produced in Canada were coal, building materials and a little iron. When the geological survey commenced active operations in 1843, a number of other economic minerals were known to exist, but only in very limited quantities. During the last 60 years, largely as a result of information furnished by the survey, the economic minerals have been developed, till now mining ranks as one of the most important industries of the country.

The total value of the mineral production of Canada for the year 1904 was $60,043,165. The geological survey adds $300,000 for the estimated value of mineral products for which no returns have been made. Of this total $31,222,525 was contributed by the metallic and $28,820,640 by the non-metallic mineral products. If these figures could be accepted as a true estimate of the relative commercial value of the two classes, it would appear that the metals contributed 52 per cent. and the non-metals 48 per cent. of the total. In estimating, however, the value of the mineral productions of a country, the methods adopted are of necessity quite different for the metals and non-metals. This arises from the fact that the value of the former, except in the case of silver, is estimated on the basis of the commercial value of the metal produced after smelting and refining; and of the latter, the value in the crude condition at the point of production. The value of the non-metallic products is therefore a very variable quantity, being so far as the consumer is concerned often largely made up of the cost of carriage to the point of consumption. The same material may thus have widely varying values at different points.

The figures I have given fail, therefore, to convey an idea of the true relative commercial importance of the two classes. If the values were based on the same conditions of production—either as mined or of the finished product—it is probable the non-metallic minerals would be found to contribute at least 75 per cent. of the total.

From a commercial point of view, therefore, the non-metals are by far the most important. If we consider human comfort the disparity is still more striking. We could contemplate with serenity the possibility of having to live without silver, but not without salt. A scarcity of gold might be inconvenient, but not to be compared in discomfort with a scarcity of coal. With the single exception of iron, the metals are objects of convenience, while many of the non-metals are necessaries of life. And even in the case of iron, we are discovering that for some purposes—certain classes of structural work for instance—it is not so necessary as it was considered a few years ago. The annual increase in the output of non-metallic products is greater than of metallic products.

The relative value of the mineral products of Canada for the year under review, each of which amounted to over a million dollars, was as follows:—(1) coal and coke, (2) gold, (3) building material, (4) copper, (5) nickel, (6) silver, (7) lead, (8) cement, (9) asbestos. Gold amounted to 27 per cent. of the total, coal to 24 per cent. The fact that gold leads is due to the large output in the Yukon, the placer mines of which are among the richest ever discovered.

It is my purpose in this paper to speak of the geographical distribution and commercial development of the non-metallic mineral products, rather than their geological relations. In dealing with such an extensive class it will be convenient to adopt some system of classification. We may with best advantage place them according to the uses to which they are put. Under this plan, they will arrange themselves as follows:—

1. Fuels.
2. Structural Materials.

3. Road-Making Materials.
4. Chemical Productions.
5. Mineral Waters.
6. Fluxes.
7. Mineral Paints.
8. Fertilizers.
9. Abrasives.
10. Refractory Materials.
11. Minor Non-Metals.

Taking these up in order, the first is

(1) FUELS.

Under fuels first in importance is coal. It is worth observing that the only coal known to occur in North America in the immediate vicinity of the seaboard, is in Canada, and that it is found on both the Atlantic and Pacific coasts—in Nova Scotia and British Columbia. The production of coal is rapidly increasing, having more than doubled within the past ten years. In 1893 it was a little over 3½ million tons, in 1904 it amounted to 7,509,860 tons, valued at $14,599,090. The coal areas of Canada are estimated at 97,200 square miles, not including areas known but undeveloped in the far north. The fields are: (1) Nova Scotia and New Brunswick; (2) Manitoba and the North-West Territories, including the Yukon; (3) the Rocky Mountains; (4) the Vancouver Island and other deposits in British Columbia. Recent explorations by Mr. J. M. Bell in New Ontario indicate the presence of coal, though the extent and commercial value of these beds is not yet fully ascertained.

The coal areas of Nova Scotia cover about 635 square miles, found in the Cape Breton, Pictou and Cumberland basins, and varying in thickness from 25 to 70 feet. To shew the extent of these deposits, if the workable area be reduced one-fourth, say from 407,400 to 300,000 acres, and the average thickness of the seams put at only 25 feet, on the basis of 1,000 tons per acre for every foot of coal, the amount in the measures of Nova Scotia is 7,000,000,000 tons, so that we need

not be apprehensive of the supply giving out in our day, or our having even to be dependent on foreign countries, which is extremely inconvenient when a strike of the miners occurs. Though a small producer, New Brunswick contains no seams of coal of any great magnitude. The Nova Scotia and New Brunswick coals are all bituminous.

The coal areas of Manitoba are roughly estimated at 15,000 square miles. They yield lignite only, but of very good quality. The Rocky Mountain area contains about 50,000 square miles, extending along the base of the mountains from the international boundary to the Peace River, a distance of 500 miles. In the mountains are the Crow's Nest Pass mines, of which we hear a great deal. Though the area is small in extent, it is very rich, containing some anthracite. The anthracite seams in the Cascade basin, adjoining the main line of the Canadian Pacific Railway, have an area of 60 square miles.

The British Columbia areas, principally on Vancouver Island, cover about 20,000 square miles. Anthracite has been found on the Queen Charlotte Islands, in quality comparing favorably with that of Pennsylvania. The Yukon deposits are chiefly lignite and cover an estimated area of 200 square miles.

The production of coal by provinces may be summarized as follows:—Nova Scotia, 5,712,128 tons; British Columbia, 1,659,741 tons; Manitoba and the North-West Territories, 604,765 tons; New Brunswick, 20,000 tons.* Of the 7,509,860 tons produced in 1904, 5,952,448 tons were consumed at home and 1,557,412 tons were exported.

The production of coke in Canada in 1904 was 543,557 tons, valued at $1,884,219, all produced in Nova Scotia, British Columbia and the North-West Territories.

Peat will probably become an important article of fuel before many years. There are immense deposits to be found in all parts of the country, but its economical manufacture into a convenient form for fuel has not yet passed the experimental stage. In 1903 the

* Figures for 1903.

quantity produced was only 1,100 tons, of the value of $3,300, nearly all of which was made in Ontario.

Petroleum is found in Ontario, Quebec, Nova Scotia, New Brunswick and the North-West Territories. In the latter there will probably yet be found valuable oil-bearing territory, but the chief source of present supply is the western portion of Ontario. For some years it has seemed as if the oil fields were being exhausted, but recent developments indicate that there is yet a bountiful supply from which to draw. The amount produced in 1904 was 552,575 barrels, valued at $984,310. A considerable amount is consumed as fuel, but the bulk is refined and used for illuminating purposes. The products of petroleum are numerous, and include illuminating and lubricating oils, benzine, naphtha, paraffin, etc.

The value of the natural gas sold in Canada in 1904 was $247,370. The output was practically all from wells in Southern Ontario, though natural gas is found in considerable abundance at and near Medicine Hat in the Territory of Alberta, where it is used to some extent for the burning of lime and locally for lighting and heating. There is a large falling off in the account for gas at one time sold, due to the action of the Government in prohibiting its export. Detroit and Buffalo, to which it was piped, were the largest customers. At the rate at which it was being exported previous to the prohibition it was evident that the supply would soon become exhausted, for a gas well is by no means a perpetual source of supply, and the action of the Government met with general approval, though it cut off a source of revenue from the counties of Essex and Welland. In 1900 the value of natural gas sold was over $417,000. In 1904 it had fallen off nearly one-half.

(2) STRUCTURAL MATERIALS.

Under the term structural materials are included all the stone used for building purposes, clays and accessory materials, including building brick, slate, lime, sand and cement. Granite, sandstone and limestone are quarried in every province. The value of building material produced in 1904 is estimated at $5,667,000; of terra cotta,

pressed brick, etc., apart from other building material, $400,000; of granite, $100,000, and of slate, which comes entirely from the province of Quebec, $23,247. The value of pottery manufactured was $200,000, sewer pipe $378,894, tiles $275,000. Of common bricks Canada produced in the census year of 1901, 371,000,000, and in the same year Ontario alone produced 3,400,000 bushels of lime, worth $520,000. So important have clay products become that in the last census a schedule was specially devoted to them.

But the most important product under this head is cement, not only on account of the annual value of the output, but because of the rapidity with which it has attained its rank among structural materials. In its importance to our present civilization it is surpassed among mineral products only by iron, coal and oil. The use of Portland cement in the construction of works, such as roadways, bridges, tanks and buildings, has increased by leaps and bounds, and as a result cement works have sprung up all over the country. The output in Canada for 1904 was 850,358 barrels, of the value of $1,197,992. The imports from all countries were 784,630 barrels, i.e., nearly as much as was manufactured at home, and as the plants in operation or under construction are of sufficient capacity to produce all that is consumed (estimated for last year at over 1,847,000 barrels), it will be seen that there is great danger of over-production, unless the home market is secured.

In addition 56,814 barrels of natural rock cement were produced, of the value of $49,397. The natural rock is cheaper and is used for foundations, silos and other coarse work, but its production is rapidly falling off.

The cement industry was established in Canada in 1891, and has steadily grown every year except 1894. Ontario is practically the only province where it is made, though steps are being taken to establish works in Manitoba, where a suitable marl is found. There are 13 factories in Ontario—four at Owen Sound, and one each at Lakefield, Hanover, Durham, Marlbank, Strathcona, Blue Lake, Raven Lake, Wiarton and Belleville. The Belleville works will use lime-

stone instead of marl. Natural rock cement works are operated at Thorold, Queenston, Limehouse and Hamilton.

(3) ROAD-MAKING MATERIALS.

It is difficult to arrive at even an approximate value of the materials used for road-making. Large quantities of sand, gravel, and stone are consumed both on common roads and on railways. Cement enters into the construction of bridges, culverts, sidewalks and concrete for roadways; sewer pipes, drain tiles and vitrified brick from among the clay products are also used in road building. A trap which makes excellent roads is found on the northern part of Lake Huron, but it has not been utilized to any extent. The asphalt for roadways is all imported. Without attempting to give definite figures, I think I am warranted in placing road-making materials high up in value among our non-metallic products.

(4) CHEMICAL PRODUCTIONS.

Salt, pyrite, arsenic, calcium carbide, acid and some minor materials come under this heading. Ontario is the only province producing salt in any quantity. As early as 1820 a few tons were manufactured from the water of salt springs at the south end of Lake Winnipegosis, Man., but the industry was not followed up. The appliances for manufacture were rude and the demand was local. Small quantities were also made for a time from brine at Plumwesup, N.B., but nothing has been done there since 1898. Salt was made near Pictou, N.S., in 1813, and a shaft was sunk 200 feet in the hope of reaching rock salt, but without result. About 30 years ago salt was made at Antigonish for a time. Salt springs are found in other places in New Brunswick and Nova Scotia, but beyond a little manufactured for local demand the output is insignificant. The salt-producing territory in Ontario includes portions of the counties of Essex, Lambton, Middlesex, Huron and Bruce. Roughly speaking, it extends from Kincardine on the shore of Lake Huron to Lake Erie, an extreme length of 150 miles, with a maximum width of 40 miles in the centre and tapering towards the ends. It covers an area of over 2,500 square miles.

Although it was known that the Onondaga formation, which is found in the above territory, is saliferous in the State of New York, the discovery that it carried salt in Canada was not made till the year 1865, when it was discovered by accident, when boring for oil at Goderich. Salt was struck at a depth of 964 feet, but boring was continued to a depth of 1,010 feet, and in that distance the drill passed through 30 feet of rock salt. Salt was discovered in a similar way in New York State.

The method of manufacture is to pump the brine and evaporate. In some cases the water infiltrating through the rocks is in sufficient quantities to be taken advantage of as a solvent, in others fresh water is put down and afterwards pumped up as brine after becoming saturated. Two processes of evaporation are employed—in vacuum or closed pans and in open pans. Each may be subdivided, the first into single effect and double effect evaporation, the second into direct fire evaporation and steam evaporation. These need not be detailed.

When salt was first discovered at Goderich the works flourished, but before long they began to languish. Having to purchase all their fuel the operators found they could not compete with Saginaw, on the Michigan side of the lake, where salt manufacturing was carried on in conjunction with lumbering. The salt blocks being situated beside the saw mills had their fuel practically free, and there being no duty on salt the Canadian market was invaded on unequal terms. In addition, the Michigan salt was coarser in the crystal and therefore better adapted for packing purposes. Experiments were made at Goderich to produce a coarser salt by solar evaporation, but they were not successful. The Goderich salt was also found to contain a large proportion of lime, which affected its properties for dairy purposes. To overcome these drawbacks Mr. Henry Atterill, a Baltimore capitalist, who spent his summers at Goderich, conceived the idea of mining the salt, and made a test with the diamond drill to ascertain the character of the beds. Borings showed a total thickness of salt of 123 feet in a distance of 388 feet, divided into six beds, varying in thickness from 6 feet to nearly 35 feet. The first bed was struck at a depth of 997 feet. It is mixed with layers of dolomite and stained by earthly

matter, and therefore not pure enough for mining. The second and third beds, struck at a depth of 1,085 feet, and 1,187 feet, are very pure, and are 25.4 and 34.10 feet respectively in thickness. The lower beds are not so pure. Mr. Atterill's company sunk a shaft for some distance, but it was never completed.

The production of salt in Canada in 1904 was 68,777 tons, valued at $318,628. It is remarkable how little the quantity has varied during the past 20 years. In 1886 it was slightly over 62,000 tons, and has not varied much from that figure till the year 1903, when it went down to less than 53,000 tons, increasing again last year to over 68,000 tons.

The amount of salt imported is about double that produced. This is not owing to a lack of sources from which the whole consumption could be derived, but to the fact that salt is produced much more cheaply in England, from which most of the import comes. The extensive salt deposits of Cheshire are close to the coal mines, so that fuel is cheap. Labor also is lower than in Canada. Salt imported from the United Kingdom, or any British possession, or for the use of the sea and gulf fisheries, is free of duty, and as vessels carry it as return freight or ballast, the whole Atlantic seaboard is monopolized by foreign salt. Of the dutiable salt imported in 1904, 14,892 tons came from the United States. The exports of salt for that year amounted to only 503 tons, so that nearly all the salt produced in Canada is consumed at home. Goderich, Seaforth, Clinton, Kincardine, Wingham, Sarnia and Windsor are the principal places of manufacture, the most extensive works being at Windsor and Sarnia, where they are carried on in connection with saw milling, thereby obtaining fuel at a cheap rate.

The production of pyrites in 1904 reached 33,039 tons, valued at $94,797. The greater part came from the two chemical works in the Eastern Townships, though a small quantity was produced in the county of Hastings, where deposits are being opened up which give promise of good results. The output is exported largely to Buffalo and Cleveland, where it is used for the manufacture of sulphuric acid.

Of arsenic there was exported 73 tons, of the value of $6,900. Complete figures of production cannot be had, but the previous year it was 257 tons, value $15,420. This was a falling off from 800 tons the preceding year. A considerable quantity of this output came from the county of Hastings. The recent remarkable discovery of cobalt ores near Haileybury, carrying a large quantity of arsenic, will no doubt result in an increase of the output.

Calcium carbide, now so much in demand for the manufacture of acetylene gas, was made to the extent of 2,343 tons, worth $164,010. The whole output was consumed in Canada.

(5) MINERAL WATERS.

Mineral springs are known to exist throughout Canada, and at many of them the water is bottled for sale, or used medicinally in its outward or inward application where found. The most interesting are the hot sulphur springs found in many places in British Columbia—at Harrison, Halcyon, Albert Canyon, and especially at Banff, N.W.T., to which sufferers from rheumatism resort with beneficial effect. The Preston sulphur springs in Ontario are also famous, but the water there is not naturally hot. It is impossible to give the value of the production of mineral waters, but it is approximated by the geological survey at $80,000 a year.

(6) FLUXES.

In the manufacture of iron, limestone is generally used as a flux. It is found everywhere convenient to the furnaces where it is required. The quantity consumed amounted to 200,646 tons, valued at $176,973.

(7) MINERAL PAINTS.

The mineral paints produced in Canada are, baryta 1,382 tons, valued at $3,702, and ochres 3,925 tons, valued at $24,995. The former comes from Cape Breton, N.S., and Hull township, Quebec, the latter chiefly from deposits near Three Rivers. White lead is made in the country, and all productions of lead have received an impetus from the bounty recently granted, but as white lead is derived from the refined metal it is not strictly speaking a mineral product.

Actinolite, found in the county of Hastings, when ground without destroying the fibre, is used in paint, fire-proof roofing material, etc., also as a filler with asbestos for pipe covering, packing, etc.

To this list may now be added cobalt, the product of the wonderfully rich ores already referred to as existing in New Ontario. As the extent of these deposits is not yet known, and as only some trial shipments have been made, the value of this discovery can only be guessed at. Cobalt is used in the arts, principally for decorating china and glass and for the dyeing of fabrics, and is worth about $3 per pound.

(8) FERTILIZERS.

The mineral fertilizers produced in Canada may be enumerated under three heads, phosphate, gypsum used as land plaster, and marls, though a considerable quantity of the lime burned is used as a fertilizer, while pyrite and sulphur are employed in making sulphuric acid, and therefore contribute indirectly to the production of superphosphates. The production of phosphate in 1904 was 917 tons, of the value of $4,590. Some of this was high grade and was employed in the manufacture of phosphorus, the balance being used as a fertilizer. The output is largely a by-product obtained in the mining of mica in those counties of Quebec lying north of Ottawa, and in the province of Ontario along the north shore of the Rideau.

Gypsum is worked in Ontario, Manitoba, New Brunswick and Nova Scotia, the latter being the largest producer. In Manitoba the beds have been worked only since 1891. The production of crude gypsum was 298,211 tons, worth $316,436, and of ground gypsum to the value of $2,333. Gypsum enters into consumption largely as plaster of Paris and as land plaster.

(9) ABRASIVES.

The group of abrasive materials contains such products as corundum, emery, infusorial earth, crushed quartz, oilstones and grindstones.

Canada has an abundant supply of corundum of a very superior quality. Corundum wheels are taking the place of grindstones to a very large extent. The discovery of this abrasive was brought to public attention in Ontario in 1896, and active mining and milling has been carried on since 1900. The most extensive deposits are found in the township of Raglan, Renfrew county, where the Canada Corundum Company has a well equipped mill and is doing a large business. Corundum is also found in the townships of Carlow and Methuen in the same range, and companies are preparing to mine and market the mineral. The quantity of rock treated in 1904 by the Canada Corundum Co., the principal producers, was 26,822 tons, and of refined corundum, 3,159,732 lbs., an increase from 1,678,833 in 1903. To this may be added 60,000 lbs. to cover the output by other producers. Refined corundum is worth about 6½ cents per pound. Of this there was sold in Canada 232,387 lbs., the rest being exported. By far the largest part of the output goes to the United States, but a considerable quantity goes to Germany, England and France. The corundum industry is rapidly growing and promises to become very important.

Infusorial earth, known also as tripoli, tripolite, diatomaceous earth, etc., is a silicious material derived from the shells of diatoms, one of the lowest forms of vegetable life. When pure it is white, but is rarely found in that condition, being usually mixed with a proportion of carbonate of lime, clay, magnesia, etc., the silica varying from 75 to 90 per cent. Diatomaceous earth is very porous, the specific gravity being .25 to .30. The uses to which it is put are very varied. It was formerly extensively used in the manufacture of dynamite as an absorbent of the nitro-glycerine, its porosity enabling it to absorb liquids to the extent of four or five times its own weight. It has, however, been replaced by cheaper absorbents, such as sawdust. It is also used as a boiler covering, as a filtering material, in the manufacture of what are known as silicate soaps, and in bricks, which can be made one-fourth the weight of ordinary bricks, but are too expensive for ordinary purposes. I have classed it with the abrasives, its chief use being for polishing. The grains are sharp and cutting, but so fine as not to scratch metal surfaces. The known important

deposits of diatomaceous earth in Canada are confined to New Brunswick and Nova Scotia. There are deposits in some of the other provinces, but so far as known too limited to be of commercial value. Further investigation will probably show that deposits in Quebec and British Columbia are more extensive than at present appears. The production in 1904 was 320 tons, valued at $6,400, a large falling off from the previous year.

The production of grindstones in Canada has varied little for the last 15 years. In 1904 it was 4,509 tons, valued at $42,782, about $9.50 a ton. Grindstones, wood pulp stones, whetstones, etc., are made from the millstone grit of the carboniferous formation which occupies a large portion of the eastern half of New Brunswick and the northern and north-western parts of Nova Scotia. The principal quarries are on the Bay of Chaleurs, Miramichi Bay and Chepody Bay in New Brunswick, and in Cumberland and Pictou counties, Nova Scotia. Other abrasives produced are of minor importance.

(10) REFRACTORY MATERIALS.

Under refractory materials are included such products as are largely or entirely used on account of their heat-resisting properties. Such are asbestos, chromite, graphite, mica and soapstone. Fire brick might also be included, but they belong more properly to structural materials.

Commercial asbestos is found in two forms—as a variety of serpentine known as chrysotile and as a variety of amphibole. The Canadian product is of the chrysotile variety. It is found in four districts in the province of Quebec, and an important, though as yet undeveloped discovery is said to have recently been made in the far northern part of that province. It is produced in two forms, the long-fibred asbestos and the short-fibred asbestic, the former worth, when of good quality, as much as $250 a ton, the latter from $1 to $3. The quantity produced in 1904 was 35,635 tons of asbestos, worth $1,167,238, and 13,011 tons of asbestic, worth $13,006. The product of the higher grades is almost all

exported, finding a market in the United States, England and the continent of Europe, and the demand is ever increasing.

Chromite is used for furnace linings and for the manufacture of chromic acid. It comes from the province of Quebec, and is perhaps more properly classed as a metallic product.

Graphite, used so extensively in the form of plumbago for making lead pencils, and for black lead and as a lubricant, is a refractory in that it is employed in the making of crucibles. It is mined in Brougham township, near Oliver's Ferry on the Rideau, in the township of Denbigh, at Buckingham, Que., and Fairville, N.B. The product in 1904 is placed at 452 tons, valued at $11,760. This is a great falling off from previous years, the census returns of 1901 having stated the output at 3,000 tons. A great deal of graphite is exported, but the imports are also considerable, and the manufacture of graphite products is becoming a not unimportant industry, 100 tons of manufactures of graphite having been turned out in 1901.

Canada is one of the world's largest producers of mica. It is mined largely in the province of Ontario and Quebec, and there is also some obtained from British Columbia. The Canadian form is what is known as white mica. With electrical development its use has grown rapidly. At one time it was employed in stove fronts, in windows and for other like purposes. It is, however, now used as an insulator in electrical machines. Fifteen years ago it had little commercial value, and when mined with phosphate was for the most part thrown aside with the waste rock. These waste heaps are now being worked over for their mica. The mica mines of Ontario are in the district tributary to Sydenham and Perth, where trimming works are situated. Mica is used extensively for boiler and pipe coverings and also in the manufacture of paint. A considerable quantity is exported to the United States and Great Britain. The value of the mica produced in 1904 was $152,170.

Micanite is a material built up of pieces of mica of all sizes and shapes by the aid of shellac cement. These mica boards can be cut and shaped with ease and are applied to almost all purposes for which mica is used.

Soapstone is produced in small quantities—1,000 tons in 1901. It is used chiefly in the manufacture of roofing cement.

Fire clay is found in British Columbia, Nova Scotia and New Brunswick. Practically the whole output is obtained in connection with coal mining, in thin beds underlying the coal seams, and is used in the construction of coke ovens and in connection with metallurgical operations. The output was 2,317 tons, value $2,505.*

(11) MINOR NON-METALS.

Among minor non-metals may be included talc, felspar, moulding sand and quartz.

Talc is produced from two deposits, near Madoc and Gananoque, in Ontario. The former is exported chiefly to Newark, N. J., where it is used in the manufacture of a cosmetic or face powder. It is also employed in the making of foot elm at Batavia, N. Y., and at Bowmanville, Ont. The Gananoque output is more fibrous in its nature and is used in the manufacture of fire-proof roofing at works in Montreal. Talc is also used in making burner tips for acetylene gas, for which a specially compact variety is required. The output of talc in 1904 was 840 tons, valued at $1,875.

Felspar is mined in the Township of Bedford, near Kingston. The production was 11,083 tons, value $21,166.

Moulding sand is of wide distribution. It is estimated that 3,423 tons were produced in 1904, value $6,790. A considerable quantity was exported to the United States.

There are some other undeveloped non-metals in Canada, but so far they have little or no commercial value and may therefore pass unnoticed.

[NOTE.—The figures given, except where otherwise stated, are those of the geological survey of Canada.]

* Figures for 1903.

MINE MEASUREMENTS.

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PREFACE.

The writer of this paper lays no claim to originality in the use of co-ordinates in this class of measurements, his only claim to that being in his manner of performing measurements herein described, the method of entering field notes, formulas used in the calculation and mode of tabulating results.

The formulas given, although very few, are all those that were found necessary in a period of about six years of work; but occasions may arise calling for the use of others, and it is hoped that the engineer who has made himself conversant with the methods here used may have no difficulty in making any new formula he may find necessary, conform to those here given.

In the specific example, given to illustrate the method of working, calculating, etc., the Metric System of measurement is used, as that system will apparently within a quite brief period come into almost universal use.

Also, as measurements of any one mine are always limited to a comparatively small area, no measurement is made more exact than to the nearest centimetre, although there is no reason for not practising greater precision when necessary.

INTRODUCTORY.

Too much importance cannot be attached to the manner of commencing the measurement of a mine, and particularly in the case

when the works already opened are extensive, or where, in a new mine with few works, there is a probability of extensive works in the future, or where, from the contiguity of two or more veins or ore bodies, it may be necessary at some future time to include the whole in one system, either for the purpose of communicating one with another, as is often the case, for the ventilation of all, or for drainage and extraction of ores from all by means of one central tunnel or shaft, as the case may be.

Probably no other method offers the same advantages for not only calculating but also tabulating the results, and finally plotting these results in a comprehensible manner as that of co-ordinates.

Two points, however, should always be borne in mind in making a beginning, and these are, to choose an origin such that the co-ordinates of every point may be positive numbers, and to form some system of naming points, such that, with the description of each point in the field notes, there may be no liability of mistaking one point for another.

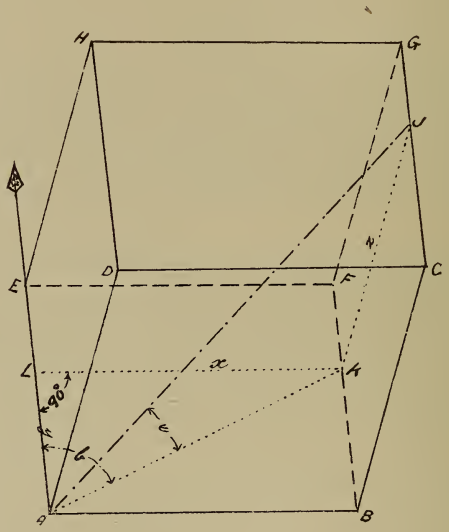
This latter is very important, for otherwise, with the multiplicity of points used in extensive works, a faulty system of nomenclature is almost sure to lead to confusion and probably subsequent great extra work in re-naming and re-tabulating all the points previously used.

Another point of importance is, in the very beginning to establish a meridian, which should be connected with not only the measurements underground, but also with the outside lines of the property.

Very often there is no way of checking the last of a series of measurements; and in such cases, to insure accuracy, one or more repetitions of the work should be made, using either the same or new intermediate points; but where a mine has several openings available to make measurements, as many as possible should be utilized in order to check the correctness of location of as many inside points as possible. Where a shaft or winze has an inclination of not more than 50° or 55°, an ordinary transit with vertical arc and an attachment for illuminating the cross hairs is all the instrument that is needed to make measurements with sufficient accuracy for most cases, but

where the inclination exceeds that amount an auxiliary telescope on one end of the horizontal axis is very convenient.

Where a winze or shaft is nearly or quite vertical, recourse is usually had to a pair of plumb lines; and to facilitate the operation of transferring bearings from one level to another with reasonable accuracy, these should be of fine wires placed as far apart as possible, and unless this distance is considerable, so located that the instrument may be set up on each level in the prolongation of the line of the wires and at such a distance from the nearer wire as to give a distinct vision.



DEDUCTION OF FORMULAS.

A B F E is a plane forming the base and *D C G H* a plane forming the top of a rectangular prism having the sides *A E H D* and *A B C D* vertical and respectively north and south and east and west. *A J* is a line running in a north-easterly direction and rising from the base to the top, so that *A K*, which is the horizontal projection of *A J*, makes angles, *b* with *A E* and *e* with *A J*; *b* is the bearing of *A J* and *e* is its angle of elevation.

Taking A as origin of co-ordinates and $A\ B$, $A\ E$ and $A\ D$ as axes, and naming them respectively the axes of X, Y and Z with distances east, north and upward from A as positive and distances measured west, south and downward as negative, and giving the small letters x, y and z their accepted signification, then the co-ordinates of J with respect to A are as follows:

$x = L\,K$ (positive), $y = A\,L$ (positive) and $z = K\,J$ (positive).

$\frac{A\,K}{A\,J} = cos\ e \therefore A\,K = A\,J\ cos\ e = A\,J\ cos$ elevation ..... (1)

$\frac{J\,K}{A\,J} = sin\ e \therefore J\,K = A\,J\ sin\ e = A\,J\ sin$ elevation .... z.. (2)

$\frac{L\,K}{A\,K} = sin\ b \therefore L\,K = A\,K\ sin\ b = A\,J\ sin$ bearing cos elevation ..... $= x$ .. (3)

$\frac{A\,L}{A\,K} = cos\ b \quad A\,L = A\,K\ cos\ b = A\,J\ cos$ bearing cos elevation ..... $= y$. (4)

Also $\frac{x}{y} = tan\ b$ ..... (5)

And calling the length $A\,J = l$, since $A\,J^2 = A\,K^2 + K\,L^2$

$= x^2 + y^2 + z^2 \therefore l = \sqrt{x^2 + y^2 + z^2}$ ..... (6)

Again, given z, b and e for the line $A\,J$, since $\frac{x}{A\,K} = sin\ b \therefore A\,K = \frac{x}{sin\ b}$

Also since ..... $\frac{y}{A\,K} = cos\ b \therefore A\,K = \frac{y}{cos\ b}$

Also since ..... $\frac{z}{AK} = tan\ c \therefore A\,K = \frac{z}{tan\ e}$

$\therefore \frac{x}{sin\ b} = \frac{z}{tan\ e}$ and $x = \frac{z\ sin\ b}{tan\ e}$ ..... (7)

Also $\frac{y}{cos\ b} = \frac{z}{tan\ e}$ and $y = \frac{z\ cos\ b}{tan\ e}$ ..... (8)

From Formula (2) it follows that $\frac{z}{l} = sin\ e$ ..... (9)

The most usual way, and probably the best way to mark points inside in a tunnel, drift, stope or winze is by means of soft pine plugs

driven in drill holes about six inches or fifteen centimetres in depth in the roof or hanging wall, and mark the point by a small wire nail driven vertically in the plug.

The head of the nail is left exposed just enough to hang a plumb line from it. Such holes are known as upper or dry holes.

To locate a transit, under such a point of which, let us suppose, the co-ordinates are already known, a simple, accurate and easy way is to place a small piece of board from ten to fifteen centimetres square, with a small nail driven in it and well embedded in earth or fine mine gravel, so that the centre of the nail is under the point of a plumb hanging from the nail marking the point.

The plumb is then removed, and after setting the transit over the nail in the board, the co-ordinates of the centre of the instrument *C I* are found by measuring vertically down from the point to the intersection of the horizontal axis with the axis of the telescope.

Where the works are already timbered, nails may be driven in the caps, stulls, etc., or where rails are laid, points may be made on the rails with a centre punch, but in both cases points are more liable to slight movement by settling or loosening than where they are marked on plugs driven in solid rock.

To locate a point ahead of one for which the co-ordinates are already given, set up the transit as already described at the known point, and, with telescope reversed, set the cross hairs on the previous point, of which also the co-ordinates are supposed to be known, or plumb line hanging from the point. Then tumble to direct position and set the large level with vernier of the vertical circle set at zero. Now, if the point ahead is visible, the cross hairs may be directed to it, but if not, they may be directed to a plumb line hanging from the point, and the telescope moved up or down till they are fixed on a horizontal line intersecting with the plumb line at a short distance below the point.

Then measure from the point where the instrument sets to the intersection of the axes, the distance from this last to the point ahead, or, if the cross hairs are set on a point below the real point, measure the distance to the auxiliary point and also from that up to the real

point. Take the angle of deflection right or left of the line and the angle of elevation given on the vertical circle. All these quantities are entered in the field book, Form No. 1, which is ruled as shown. Also enter the compass bearing, which serves as a check on the angle of deflection, and a thorough description of the point. Note also the back sight.

Where no more convenient method is at hand, a small piece of board of a known length and both ends cut square, may be held against the plug at the nail. The intersection of the lower end with the plumb line may be taken as the foresight.

In the example given in the following pages, such a board about 60 centimetres in length is supposed to be used.

Exception may be taken to making a measurement to or from a point which cannot be reached, that is, the intersection of the axis of the telescope with the horizontal axis about which it revolves, but really as the engineer may always do this personally, he will find with a little practice that whether the measurement be horizontal, vertical, or inclined, he can bring the error within one or two millimetres if necessary.

Where no instrument of any kind is at hand, an inclination may be taken by holding the edge of one branch of a square against the upper or lower side of a long straight-edge set at the required inclination, and then take the readings where either one of the upper or lower edges of a carpenter's level, held against the side of the square, intersects the branches.

The readings will give the natural tangent of the angle as may be seen by a sketch made on paper as described.

EXAMPLE SHOWING MANNER OF WORKING, ETC.

To illustrate the method of making measurements and the calculation, let us take as a practical example, the northern slope of a hill which runs, more or less, from east to west in which a vein, running from south-east to north-west, outcrops in various parts of the hill side, and indicating that it dips to the north-east at from 30° to 50°.

Suppose that at the level selected to begin operations, chosen on account of favorable conditions of the ground, there is no visible outcrop of the vein, and a tunnel has been run to crosscut the vein from the side of the hanging wall. After cutting the vein, the tunnel is turned along it and the hanging wall, which is intact, shows a bearing of about *S.* 40° *E.*

At convenient distances, winzes have been sunk on the dip of the vein, which is there shown to be from 40° to 50°.

In the first winze, at a depth of about 30 metres, a level has been run along the vein in both directions for development and ventilation as soon as the other winzes are cut.

All the winzes are continued downward on the vein below this level, and in the first one a dislocation or fault is found at 20 metres. In the next winze south from the first, the fault is found at about 25 metres, while in the following one it is found at about 30 metres. In a winze to the north of the first one the fault is found at about 15 metres with indications that below the fault, which cuts the vein nearly at right angles, the vein will be found in the direction of the hanging wall. Each winze, at the point where it reaches the fault, is changed to a drift with the same bearing as the winze and in all, at from 15 to 18 metres, the vein is found with strike and dip approximately as above the fault.

Finding the fault as given by the measurements indicates of course that its strike is more nearly east and west than is that of the vein.

At this point in the work it is seen that further development without a large hoist, instead of the hand windlasses which have been used until now, is impracticable, and it is decided on to sink a large shaft from the surface and put up the necessary machinery.

In the different winzes it is found that, excepting the most northerly one, the fault is made up of a series of parallel stringers and the work indicates that in opening up a large shaft, heavy timbering and dangerous work will be necessary, whereas in the remaining winze there is only one stringer with firm rock that will need, at most, light timber, and little danger of caving.

Also it is desired to have the mouth of the shaft as near as possible to the present tunnel, so it is decided to open the shaft on an incline, and, if possible, so that it may cut the fault at the point mentioned.

Up to this time no measurements excepting very rough ones have been made, so an engineer is called in to make an accurate survey to see if a shaft with an inclination a little less than the dip of the vein and otherwise as already described, is practicable. This difference of the inclination is because it often, although not always, happens that another, deeper fault will again move the continuation of the vein in the same direction as the first and in such a case the shaft, with depth, will also approximate in that direction so that cross-cuts from the different levels of the shaft to the vein may be shorter.

The engineer, after fixing a permanent point near the mouth of the tunnel and establishing a meridian, proceeds to locate his inside points in such a way that he may from any point see the immediate back and forward points and in the winzes selects points where the instrument may be set up with the least possible trouble and danger.

As it is desired to connect that portion where it is desired that the shaft shall pass the fault, with the surface, no measurements but those necessary are now made except such as where to set up the instrument is difficult; once set up, a measurement may be more easily made to a following point than to have to re-set at the difficult point, so commencing at *A*, the measurements recorded in Form No. 1 are made.

The notes as taken in Form No. 1, in a field book, show the distance from *A* to *B* as 18.41 metres, measured 35° 20′ to the right from *M A*, and with an inclination upward of 1° 18′ and a compass bearing of *S.* 24° *W.* This is taken as a rough check on the deflection.

At *A* the instrument is set up so the intersection of the axis of the telescope with the horizontal axis is 1.48 metres above the point *A*, and this distance is put in the right hand or plus column of *H I*, which is height of instrument, and on the same line of the book with *A*. At *B* a point is taken at a distance of 0.60 metre below the nail and this distance is put in the left hand or plus column *F.S.*, which is

fore sight, and on the same line of the book with *B*. The back sight is noted.

The measurement is made continuously as far as *F*, and then in place of moving the instrument from *E*, which is a difficult point to set up on, measurements are taken to *G* and *H*, using the same back sight, *D*, and the same *H I*, that is, 0.77 metre below the point *E*, and this distance, it will now be noted, is now put in the left hand or minus column of *H I*, and on the same line with *E*.

Particular attention should be paid to the vertical measurements made up or down at the instrument and at the fore sight.

There will always be such measurements at the instrument where, if the point is below the instrument the distance will be positive and is put in the plus column of *H I*, and on the same line with the point where the instrument sets.

If the point is above the instrument, the distance will be negative, for it forms a portion of the measurement from one point to the other, and in going along the measured line, this distance is in the negative direction, therefore it is put in the minus column of *H I* and in the same line with the point.

At the fore sight there may or may not be a measurement, for very often the point may be taken directly, and in which case there is no measurement, but zero is marked in that column of *F S*, which indicates whether the point is above or below where the instrument will be set there.

When there is a measurement made at the fore sight it is entered in the field book, always on the line with the point to which it corresponds. If the point on which the cross hairs are set is below the real point then the measurement is positive and is put in the plus column of *F S*, but if the point on which the cross hairs are set is above the real point, as when this is on a rail, the distance down to the real point is negative and is put in the minus column of *F S*.

These distances are transferred to Form No. 2 just as they are in the field book, and it must be remembered in the calculation of *Z* for any line, that if there are vertical measurements at both the instrument

and fore sight, the one at the instrument is recorded on the line above that on which the one taken at the fore sight is recorded.

As the writer had some difficulty in avoiding errors on this account, in the first measurements he made with this system, special mention is made of it now.

Where a vertical winze or shaft is measured, the distances measured vertically, although very much greater than those given in the example, may be entered in the field book, in the columns *H I* and *F S*, while any legal or inclined measurement made with the instrument set at the same point may be entered as usual in the other columns.

After the measurement is completed, the data, excepting the compass bearing, is transferred to Form No. 2, ruled as shown, in a cross-section book or a book of the same size of unruled paper which may be ruled as needed with alternate double pages for Form No. 2 and Form No. 3. The writer, using one double page for Form No. 2 and the following one for Form No. 3, finds room for eighteen measurements on the first and eighteen calculations on the following double page.

In Form No. 2, so ruled, the distance, deflection angle and angle of elevation are put on the left hand page on a line ruled half way between those of the points which they connect, while the distances measured vertically at the instrument and the fore sight are each put on the line of its corresponding point on the opposite page.

In Form No. 4 is given the calculation of the bearings of all the points, starting from *M A*, which is north and south.

Pages may be ruled for this in the back part of the same book, and after calculating the bearing of all the lines of a continuous measurement, the difference of the sums of the right and left deflections gives a check between the first and last bearings. Also it is better to preserve these calculations, properly indexed, in order to find any error made, than to make them on scraps of paper which are then thrown away.

From Form No. 2 the lines with length, bearing and angle of inclination are transferred to Form No. 3 and calculated by formulas

2, 3 and 4 given on page 41. The Form No. 3 is ruled in sections of four lines each, and each section divided into four columns. Thus, in first line of first column of first section is put the line *A B* with its length, 18.41 metres. In the second line is the bearing, *S.* 35° 20′ *W.*

In the third line is put the angle of inclination, plus or up 1° 18′. The other three columns are marked *X, Y* and *Z*. In each of these columns, on the top line, is put the logarithm of 18.41 as shown. On the second line is put the *L sine* of 35° 20′ in column *X* and the *L cosine* in column *Y*.

On the third line is put the *L cosine* of the inclination, 1° 18′ in columns *X* and *Y* and the *L sine* of the same angle in column *Z*.

Now in column *X* are the logarithms of the three quantities of formula 3, and their sum is the logarithm of the departure of the line. Similarly in columns *Y* and *Z* are the logarithms of the quantities in formulas 4 and 2 respectively, so that the sums give the logarithms of the latitude and difference of level of the line. As the bearing is southwest, both the latitude and departure of the line will be negative; also as the angle of inclination is upward, *Z* will be positive.

After calculating the lines the results are carried to Form 2 on the left hand page as shown, and having assumed the co-ordinates of *A* as shown, *X*=1000.00, *Y*=500.00, *Z*=300.00, metres of course being the unit, the co-ordinates of the remaining points are calculated as in Form No. 5. Taking for example the line *A B;* the departure is negative, therefore the *X* of *B* becomes 989.36. The latitude also is negative, therefore the *Y* of *B* becomes 484.98. In the next columns we have three quantities, all positive, and their sum added to the *Z* of *A* makes the *Z* of *B* become 302.50. These three quantities are: 1.48 metres measured up from *A* to the axes of the instrument, 0.42 metre, that the line rises, and 0.60 metre, measured up from the point taken at fore sight to *B*.

Similarly the co-ordinates of the remaining points are calculated, leaving only *G* and *H* to be done when needed.

The line from *A* to *F* is re-measured and the first result found to be near enough to be satisfactory.

If possible, it is desired to use a point vertically below F as a point in the centre line of shaft, and as a trial the engineer calls this new point S_2 with co-ordinates the same as F except the Z, which is taken as 281.50.

Also it is decided to use as bearing of the shaft, from the surface downward, *N.* 51° *E.*, which is nearly the same as that of the winze *F J*, and with an inclination of 40°, to see where the centre line would come to the surface.

This is done by means of formulas 7 and 8, page 41.

The difference of level, Z between S_2 and the surface at A is 18.50 metres and the calculation is as follows:

$$x = \frac{18.50 \times \sin 51^\circ}{\tan 40^\circ} \qquad y = \frac{18.50 \times \cos 51^\circ}{\tan 40^\circ}$$

Log 18.50 = 1.267172	1.267172
L sin 51° = 9.890503	*L cos* 51° = 9.798872
11.157675	11.066044
L tan 40° = 9.923814	*L cos* 51° = 9.923814
1.233861	1.42230
$x = -17.13$	$y = -13.88$

As the bearing of the shaft from S_2 to the surface is *S.* 51° *W.*, X and Y will both have a minus sign.

	X	*Y*	*Z*
S_2.....	1006.28	499.48	281.50
	— 17.13	— 13.88	+ 18.50
S_1.....	989.15	485.60	300.00

This shows that S_1, where the centre line of shaft is at the level of A, is very near B, where the tunnel first cuts the vein and by a reconnaissance outside with a level it is thought that by making an excavation at a level of 12 metres above A, the shaft will come to the surface at a point where there is a favorable location for a boiler and hoist room and also space on the same level for other buildings, a water tank and a wood yard, which is necessary as wood will be the fuel used.

Measurements on the surface show that this is about correct and excavation for the site is commenced.

But to complete the shaft as soon as possible work is commenced at F both upward and downward, while at B, the original tunnel is amplified in order to pass outside the shaft and work is commenced there also up and down in the line of the shaft.

At F and another point located in the winze, $F\ J$ below F, lights are suspended on the centre line of shaft, as guides, and as soon as three or four metres of shaft are opened from the level of B, guides are also located there.

As the point is liable to be lost at F by giving to the shaft its necessary amplitude, a couple of new points are located in the drift on both sides of F to facilitate the re-location of a new point when convenient to do so.

To find the length of shaft from the surface at S to S_2, for example, use the formula No. 6 given on page 41.... $l\sqrt{x^2 + y^2 + z^2}$

As a triangulation is the only practicable method of measuring accurately over very rough ground, the engineer in this way locates the corners of the property and connects with the point A so that he may calculate the co-ordinates of the monuments with reference to the same origin used in the inside measurements.

Objection may be made to the conditions and operations herein described as being purely imaginary and not likely to be found in actual work, still every one of them and many more have occurred in the writer's practice, and most of them in a much more complicated manner, and while it is quite improbable that an actual case with all the conditions here given should occur, it is probable that in any extended experience all might be met separately.

Where two points on the same level are to be connected by a drift along one well marked wall of a vein, the level is the only thing of importance to be fixed; and once fixed at both ends work may be done from both ends.

Where two points at different levels are to be connected by a winze running along one well marked wall of the vein, the bearing only is

of importance, and once given at both ends, work may be done from both ends.

Where, on account of a high elevation, that is, greater than 50° or than 55°, it is necessary or convenient to use an auxiliary telescope on one end of the horizontal axis, it is obvious that the fore sight must be taken with the cross hairs of this telescope set on a point which is the same distance from the true point as that between the axis of the two telescopes and measured parallel to the axis about which they revolve.

A little reflection will show that as the angle of elevation of a line increases, any instrumental error made in transferring a bearing from one level to another is augmented more and more, and when the elevation approaches 90° a transit is altogether unreliable for such an operation.

In very extensive works, where the points are very numerous, it would be well to have a special book for the points and their co-ordinates, with room for description of the points and any other data about each point that it might be of interest to note from time to time, as moved, fallen, covered, etc.

FIELD BOOK. FORM No. 1.

Points	Dist.	Deflection R. or L.	Angle of Inclination	Compass Bearing	N. I. −	N. I. ×	F. S. +	F. S. −	B. S.	
A						1.48			M	A is pt. on rail at mouth of tunnel and M A is north south, M is on meridian of A.
	18.41	R. 35°-20′	+ 1°-18′	S. 24° W.						
B					0.73		0.60		A	B is plug at intersection of tunnel with view. In roof.
	29.48	L. 74°-44′	+ 0°-56′	S. 50°-30′ E.						
C					0.82		0.60		B	C is plug in roof of tunnel at winze No. 1
	16.76	L. 88°-13′	− 44°-25′	N. 41° E.						
D					0.66		0.60		C	D is plug in roof of winze No. 1, between tunnel and next second level.
	13.52	L. 2°-16′	− 40°-16′	N. 39° E.						
E					0.77		0 60		D	E is plug in roof of winze No. 1, at second level.
	30 23	L. 89°-32′	+ 0°-41′	N. 50°-30′ W.						
F							0.60			F is plug in roof of 2nd level at 1st winze north of No. 1.
	19.65	R. 1°-8′	− 43°-11′	N. 40° E.						
G							0.60			G is plug where winze No. 1 cuts fault. Inst. still at E B A is D.
	29.25	R. 89°-17′	+ 0°-27′	S. 50′ E.						
H							0.00			H is plug in 2nd level at 1st winze south of No. 1 Inst. at E same B S.
F					0.69				E	Inst. moved from E to F
	14.49	R. 90° 13′	− 42°-50′	N. 41° E.						
J					0.71		0.60		F	J is plug in 1st winze north at fault.
	16.63	R. 2°-03′	-- 1°-05′	N. 43° E.						
K							0.60			K is plug 1st winze north cuts vein below fault.

FORM No. 2.

Points	Dist.	Delf. R. or L.	Bearing	Angle of Elev. Up +	Angle of Elev. Down −	Lines-Lat. Dep. and Change of Level +X	−X	+Y	−Y	+Z	−Z	H. I. (Z) Up −	H. I. (Z) Down +	Co-ordinates of Points X	Y	Z	Fore-sight Up +	Fore-sight Down −	Back Sight
A													1.48	1000.00	500.00	300.00			M
	18.41	R. 35°-20′	S. 35°-20′ W.	1°-18′			10.64		15.02	0.42									
B												0.73		989.36	484.98	302.50	0.60		A
	29.48	L. 74°-44′	S. 39°-24′ E.	0°-56′		18.71			22.78	0.48									
C												0.82		1008.07	462.20	302.85	0.60		B
	16.76	L. 88°-13′	N. 52°-23′ E.		44°-23′	9.48		7.31			11.73								
D												0.66		1017.55	469.51	290.90	0.60		C
	13.52	L. 2°-16′	N. 50°-07′ E.		40°-16′	7.92		6.62			8.74								
E												0.77		1025.47	476.13	282.10	0.60		D
	30.23	L. 89°-32′	N. 39°-25′ W.	0°-41′			19.19	23.35		0.36									
F												0.69		1006.28	499.48	282.29	0.60		E
	14.49	R. 90°-13′	N. 50°-48′ E.		42°-50′	8.23		6.72			9.85								
J												0.71		1014.51	506.20	272.35	0.60		F
	16.63	R. 2°-03′	N. 52°-51′ E.		1°-05′	13.25		10.04			0.31								
K														1027.76	516.24	271.93	0.60		
D																			
			N. 50°-07′ E.																
E												0.77							D
	19.65	R. 1°-08′	N. 51°-15′ E.		43°-11′														
G																	0.60		"
	29.25	R. 89°-17′	S. 40°-36′ E.	0°-27′															
H																	0.00		"
S_2														1006.28	499.48	281.50			
							17.13		13.88	18.50									
S_1														989.15	485.60	300.00			
							11.11		9.00	12.00									
S														978.04	476.60	312.00			

CALCULATIONS. FORM No. 3

		X.		Y.		Z.	
AB	18.41	1.265054	Log.	1.265054	Log.	1.265054	Log.
5.35°-20′ W.		9.762177	L. Sin.	9.911584	L. Cos.		
+1°-18′		9.999888	L. Cos.	9.999888	L. Cos.	8.355783	L. Sin.
		1.027119	−10.64	1.176526	−15.02	7.620837	+0.42
BC	29.48	1.469527	Log.	1.469527	Log.	1.469527	Log.
5.39°-24′ E.		9.802589	L. Sin.	9.888030	L. Cos.		
+0°-56′		9.999942	L. Cos.	9.999942	L. Cos.	8.211895	L. Sin.
		1.272058	+18.71	1.357499	−22.78	7.681422	+0.48
CD	16.76	1.224274	Log.	1.224274	Log.	1.224274	Log.
N. 52°-23′ E.		9.898787	L. Sin.	9.785597	L. Cos.		
−44°-25′		9.853862	L. Cos.	9.853862	L. Cos	9.845018	L. Sin
		0.976923	+9.48	0.863733	+7.31	1.069292	−11.73
DE	13.52	1.130977	Log.	1.130977	Log.	1.130977	Log.
N. 50°-07′ E.		9.884994	L. Sin.	9.807011	L. Cos.		
−40°-16′		9.882550	L. Cos.	9.882550	L. Cos.	9.810465	L. Sin.
		0.898521	+7.92	0.820538	+6.62	0.941442	−8.74
EF	30.23	1.480438	Log.	1.480438	Log.	1.480438	Log.
N. 39°-25′ W.		9.802743	L. Sin.	9.887926	L. Cos.		
+0°-41′		9.999969	L. Cos.	9.999969	L. Cos	8.076500	L. Sin.
		1.283150	−19.19	1.368333	+23.35	7.556938	+0.36
FJ	14.49	1.161068	Log.	1.161068	Log.	1.161068	Log.
N. 50°-48′ E.		9.889271	L. Sin.	9.800737	L. Cos.		
−42°-50		9.865302	L. Cos.	9.865302	L. Cos.	9.832425	L. Sin.
		0.915641	+8.23	0.827107	+6.72	0.993493	−9.85
JK	16.63	1.220892	Log.	1.220892	Log.	1.220892	Log
N. 52°-51′ E.		9.901490	L. Sin.	9.780968	L. Cos.		
−1°-05′		9.999922	L. Cos.	9.999922	L. Cos.	8.276614	L.Sin.
		1.122304	+13.25	1.001782	+10.04	7.497596	−0.31

CALCULATION OF BEARINGS. FORM No. 4.

Points	Bearings	Deflections R.	Deflections L.	
A		35°-20′		M is *B.S.* at *A* and *MA* in north south.
	S. 35°-20′ W.			
B			74°-44′	39°-24′ 180°-00′
	S. 39°-24′ E.			+ 88°-13′ − 127°-37′
C			88°-13′	127°-37′ N. 52°-23′ E.
	N. 52°-23′ E.			
D			2°-16′	
	N. 50°-07′ E.			
E			89°-32′	
	N. 39°-25′ W.			
F		90°-13′		
	N. 50°-48′ E.			
J		2°.03′		
	N. 52°-51′ E.			254°-45′ N. 52°-51′ E.
K		127°-36′	254°-45′	− 127° 36′ R. 127°-09′
				127°-09′ 180°-00′ = N. S. – Check.
D				
	N. 50°-07′ E.			
E		1°-08		Inst. still set at E and deflection to H is from line D E.
	N. 51°-15′ E.			
G		89°-17		
	S. 40°-36′ E.			
H				
				Note—This form is ruled so that deflection angle is given on same line with point where it is taken and in this differs from forms No. 1 and No. 2 where the deflection angle is on line between that of point where it is taken and following point.

CALCULATION OF CO-ORDINATES FORM No. 5.

	X	Y	Z				
				+	0.42		
A	1000.00	500.00	300.00	+	1.48		
				+	0.60		
	10.64	− 15.02	+ 2.50	+	2.50		
B	989.36	484.98	302.50	+	0.48	+	1.08
				+	0.60	−	0.73
	+ 18.71	− 22.78	+ 0.35	+	1.08	+	0.35
C	1008.07	462.20	302.85	−	11.73	−	12.55
				−	0.82	+	0.60
	+ 9.48	+ 7.31	− 11.95	−	12.55	−	11.95
D	1017.55	469.51	290.90	−	8.74	−	9.40
				−	0.66	+	0.60
	+ 7.92	+ 6.62	− 8.80	−	9.40		8.80
E	1025.47	476.13	282.10	+	0.36	+	0.96
				+	0.60	−	0.77
	− 19.19	+ 23.35	+ 0.19	+	0.96	+	0.19
F	1006.28	499.48	282.29	−	9.85	−	10.54
				−	0.69	+	0.60
	+ 8.23	+ 6.72	− 9.94	−	10.54	−	9.94
J	1014.51	506.20	272.35	−	0.31	−	1.02
				−	0.71	+	0.60
	+ 13.25	+ 10.04	− 0.42	−	1.02	−	0.42
K	1027.76	516.24	271.93				
F	1006.28	499.48	282.29				
			− 0.79				
S_2	1006.28	499.48	281.50				
	− 17.13	− 13.88	+ 18.50				
S_1	989.15	485.60	300.00				
	− 11.11	− 9.00	+ 12.00				
S	978.04	476.60	312.00				

DISCUSSION BY PROF. STEWART.

I have read with much interest Mr. Lott's description of his method of making a survey of a mine, and am pleased to find that in the main his method coincides with my own. The use of co-ordinates in determining and registering the relative positions of the stations of a survey has always appeared to me to be the best, as it enables the surveyor to make an accurate plot of his work and also furnishes him with the data for solving any problem that may occur in the working of the mine. In one or two minor particulars my practice deviates slightly from his. For instance in measuring the horizontal angles at the stations I prefer to use the "traverse method," whereby the angle read off on the horizontal circle is the astronomical azimuth of the course, a meridian having been established at the outset and its direction taken as that from which the horizontal angles are to be measured. In this way the necessity for computing the bearings afterwards is obviated, although the bearings reckoned in this way may have any value between 0° and 360°. The formulæ given by Mr. Lott are still applicable, by giving to the sine or cosine of the bearings its proper algebraic sign. Also in reducing the angle and linear measurements of the survey to co-ordinates it is not necessary to take two of the axes of co-ordinates as coinciding with the meridian plane, but one of the axes may be taken parallel and another perpendicular to the strike of the vein or veins that are being worked, assuming them to be approximately parallel. This necessitates correcting each of the bearings by applying a constant angle, equal to the azimuth of the strike of the veins. Then by plotting the X and Z co-ordinates a vertical section of the mine parallel to the strike is obtained, while the Y and Z co-ordinates give a vertical section perpendicular to the strike; a plan is obtained by plotting the X and Y co-ordinates. In addition to this, the three drawings indicated will enable the surveyor to make a graphical solution of any problem that may occur in the mining operations, which may be used as a check upon the numerical calculation. A contour plan of the surface of the ground within the limits of the location is also of service in this connection, the elevations being of course referred to the same datum plane as that of the mine survey.

I consider that the thanks of the society are due to Mr. Lott for a very useful and interesting paper.

NOTES ON GOLD MINING IN MEXICO.

ALEXANDER H. SMITH,

Superintendent Los Reyes Gold Mining and Milling Co., Oaxaca, Mexico.

Naturally the first requisite for these notes is the gold mill properly situated and with enough ore to feed it. This is a self evident fact till one travels on the hurricane deck of a Mexican mule over mountains and down narrow canons to be dumped off at last in front of a modern stamp mill, solid mortars and everything intact; then the self evident fact appears a miracle as far as the mill is concerned, and one is forced to crib an old verse and ask,

"How did it get thar? Angels."

"Angels," scarcely answers the question as a general rule. It has first of all been the knowledge of a good paying mine, the energy displayed by the men who have found it, and the numerous peons, oxen, mules and burros that have been employed to move in the machinery.

The mines of Los Reyes Gold Mining and Milling Company are situated about thirty-two miles west of the City of Oaxaca, in Southern Mexico. To reach them, a high mountain, San Pablo, of the Sierra Madre range, has to be scaled, and a descent made on the other side to the Canon de San Miguel Peras. Oaxaca lies at some 5,000 feet elevation; the top of San Pablo mountain is 10,000 feet, and the Hacienda Los Reyes at 6,500 feet. The road for the first fifteen miles to the bottom of San Pablo is only fair; from this point the grades to the top are over 15°; from the top of the mountain to San Miguel Peras the grades are lower, but the road is generally in terrible condition. Over this road a complete twenty-stamp mill was moved, besides an electric equipment comprising a 40 K. W. generator

and motors for supplying power for a 30-horse power air compressor, pumps and electric lighting of a mill and works. Small pieces were transported on mule back, larger pieces on wagons, with the assistance of block and tackle. The large iron pulleys for water wheels were rolled in by men, a shaft being put through the hub and two forked sticks lashed to the shaft, one in front for pulling, and one behind for pushing. Most of this work was done in the rainy season, thus adding to the difficulty. This is only an instance of difficulties experienced in the installation of mining plants in Mexico, and can be taken as a fairly easy proposition, for in many instances the mines are situated ten to thirty days' travel from the railroads, and still are equipped with solid and modern plants.

The mill equipment of Los Reyes consists of a Blake rock crusher, twenty 850-lb. stamps and two New Standard concentrators, the whole being driven by a 5-foot double-nozzle Pelton water wheel under a head of 79 feet, and capable of developing 60 horse power. At the top of the mill a patio capable of holding 3,000 tons of ore is situated; below this patio are placed two 40-ton bins; one is dumped on two sets of grizzlies, 4′ x 10′, $2\frac{3}{4}$″ taper bars with 2″ openings, one set for each bin. The over size passes to the crusher and drops into the bins below. Each bin supplies a battery of ten stamps, the ore being fed by Challenge ore feeders.

The mortar blocks, 2′ 6″ x 4′ 8″, are built up from bed rock with 2″ rough sawn lumber spiked together with 4″ nails; the joints are broken by varying the width of plank, a 14″ and a 16″ plank to start with, making up the width of 30″, followed by a layer of three 10″ planks, then by another 14″ and 16″, and so on till the length of the block is completed. These mortar blocks have been in continuous service for over two years, and have shown no unequal settling. Another feature in the building of foundations and frames for the battery has produced excellent results; that is, to run a post directly under the battery posts, which in this case is 12″ x 24″, down to the bottom of the mortar blocks. In most mills, designed with wooden frames, the battery posts rest on a sill which is in turn supported by mud sills, generally placed the width of the mortar blocks apart; but

no matter what the dimensions of the sill upon which the battery posts rest, a certain vibration occurs. If, however, a post, say 12″ x 12″, be run down to the foundation, this vibration is considerably reduced, and the result is a firm battery post, a reduced vibration of the cam shaft, longer life to the bearings, and not so much danger of having the cams, shaft, or bearings broken.

Where a stamp mill is situated a distance from railroads or machine shop, it is absolutely necessary to see that foundations and frames are properly designed and constructed, and to eliminate as much as possible the chances of breakage; for this purpose, many of the running and wearing parts should be constructed of steel, the utmost care being taken that the bearings of the cam shaft are of good proportions, and stems and guides of strongest design. To properly describe a mill that has given excellent results, rough specifications are given below:

Challenge Automatic Feeders, tappet driven, wood frames, sheet-iron hoppers.

10 stamp batteries, 850-lb. stamps, arranged to run in batteries of 10.

High mortars, each about 5,500 lbs. weight, planed upon bottom, and four screen frames, with foundation bolt holes for 1½″ x 36″ anchor bolts drilled to template, mortars arranged inside for copper plates, front and back, and provided with protection plates or side and end liners.

Stamp shoes and dies of steel.

Boss heads, semi-steel, bored for stems and recessed for shoes.

Stems of best refined steel, 3⅛″ x 14′.

Three key tappets, 12″ long, faced on both ends.

Cams, steel, five right and five left hand for each battery, provided with patent fasteners.

Heavy hammered iron or best quality steel cam shaft, 5⅝″ diameter, turned full length with proper key-ways for cams.

Heavy corner cam shaft boxes, 12″ long, babbitted.

Jack shafts, not turned, hard wood fingers with iron sockets lined with leather.

Sectional iron stamp guides.

Rubber packing, $\frac{1}{4}''$ thick, for top of mortar blocks for mortars to rest upon.

Main line turned shaft $3\frac{5}{8}''$ diameter, with well designed long pillow blocks.

Cam shaft wooden pulleys, $84'' \times 15''$.

Ore bin gates, $20'' \times 24''$, with rack and pinion slides, hand wheel, etc.

Necessarily a stamp mill is under constant vibration and this causes breakages, which are increased if the mortar blocks are not firm, but apt to settle. The bearings of the cam shaft, if not of good heavy proportions, are apt to crack if a flaw occurs in the wooden battery posts. If the straight post design is used, braced behind from the ore bins with horizontal timbers, it is well to run a stout brace immediately below the bearings and tie everything at this point with heavy iron tie rods. A badly aligned cam shaft is accountable for many accidents, breaking cams and stems and causing unequal strains on the driving shaft. Having five right and five left hand cams in each battery, helps immensely in the smooth running of the cam shaft. Properly aligned stem guides are also necessary, and for this purpose sectional iron guides are superior to solid wooden ones, and also facilitate the reversing of the stems when broken. All shafting should be of good size and well supported with the best designed bearings.

Where it is possible, heavy solid mortars are infinitely superior to sectional ones; a leak in a mortar is dangerous, as the first thing to pass through the leak is amalgam or quick. If sectional mortars are used, bolts will be found to give better satisfaction than rivets, as they can be put in place quickly and tightened when necessary. Again, steel side liners, in addition to the mortars, will give a long life to these heavy pieces, which is important in isolated districts. If an inch or more of clay or sand be put under the dies so as not to let them rest directly on the bottom of the mortar, cupping is reduced, giving a longer life to the bottom of the mortars.

When a foundry is close at hand, iron shoes and dies are more economical. El Oro gold mines, for instance, work up their accumulated scrap iron for this purpose, but where there are no facilities of this description, steel is preferable. The most suitable shoes and dies for the class of ore milled should be one of the first things determined, in starting the mill. Take what you consider the average class of ore likely to be milled, and watch results obtained by a number of different makes of shoes and dies. This can easily be determined by putting, say two of one kind and three of another, in a five stamp mortar. A difference of ten or fifteen days in the life of these wearing posts makes considerable difference in milling costs.

It may seem redundant to recite all these details, but it is a fact that many engineers look on the stamp mill, from an academic point of view, as simply a shaft with a number of cams attached for the purpose of lifting and letting drop an equal number of stamps; they are apt to forget that the stamp mill in full running order is continuously under a tremendous jar and vibration, and it is a mill that, to get good service from, must run twenty-four hours a day, and be kept running for a month at a time without stopping. Also in properly regulated mills, the absolute necessity of smoothly running shafting and elimination of breakages is quickly proved by cost sheets.

The character of ore produced by Los Reyes mines is free milling, hard, brittle quartz, well mineralized with sulphides, iron pyrites, marcasite, pyrrhotite and traces of arsenopyrite and copper pyrites. In milling, care is taken that the percentage of sulphides is not too high; if the sulphides run above 10%, the extraction is lowered. This is not on account of the sulphides not being free milling, but because the sulphides, especially the pyrrhotite, slime in the mortars, coating the plates with a thin coat of slime, making them less sensitive and requiring frequent dressing; also the fine sulphides sicken the quick, and a loss of amalgam and quick occurs.

Inside and outside amalgamation is practised. In each mortar a back plate, 50″ x 10″, and a front plate, 50″ x 5″, is placed. A 40-mesh double-crimped steel screen is used; the usual height of drop is 6″, and height of discharge, from 5″ to 6″, the stamps dropping from 85 to 90 per minute. The pulp on being discharged from the

mortars, is carried through two-inch pipes to four sets of plates situated about twenty feet away from the batteries and on a lower floor. Each table is divided longitudinally by a wooden strip, $1\frac{1}{2}'' \times 1\frac{1}{2}''$. Each table has four plates, 48″ long by 58″ wide, of $\frac{1}{8}''$ silver plated copper plates, two ounces silver to the square foot. They are designed so that the fall can be regulated. Experience proves that the most suitable fall is $1\frac{5}{8}''$ to the foot. Falls of 1″, $1\frac{1}{2}''$ and 1″ are made at the end of each plate. At the bottom of the tables suitable amalgam and quicksilver traps are situated, the tailings passing through wooden launders to storage pits. Sufficient water is fed to the batteries to make the pulp flow evenly over the outside plates, and if many sulphides are present in the ore, the water supply is increased to prevent banking.

Mercury is fed into the mortars every half hour, the amount being regulated by the richness of the ore. If too much is added it is quickly noted by the appearance on the outside plates of "tears." If the ore is heavily mineralized, quick lime is added to the feeders in the proportion of about a pound to the ton. When changing screens, if the inside plates appear coated with sulphides, or are dirty, a small amount of sodium amalgam is added, together with a piece of cyanide as large as an almond. The outside plates are dressed every hour with a whisk broom and clean water, the longitudinal wooden strip allowing this to be done without hanging up any of the stamps. If staining appears, a weak solution of potassium cyanide is used to remove it. The amalgam on the outside plates is only cleaned up every two or three days, and is allowed to accumulate as much as possible before removal.

A leaf from the Amalgam and Bullion Record Book of the company may be of interest, showing where the amalgam collects and percentages. This is the record of 10 stamps running 30 days, 13 hours, and crushing 573 tons, from December 11th, 1904, to January 11th, 1905, and is typical of results, not of values or tonnage, but of amalgam, and bullion produced from this amalgam:

Weight of outside amalgam.....	7.930 kilos=	36%
Weight of inside amalgam.....	22.070 kilos=	64%
Total.....	30.000 kilos=	100%

Weight of retort gold .....11.575 kilos.
Weight of bar gold .....11.235 kilos.

Loss due to impurities in retort..... 0.340 kilos.

Per cent. of gold in amalgam.....37.4

This bullion had a fineness of 923.7 gold, 69.1 silver, the impurities being copper from plates, and caps in the ore; and perhaps a little arsenic and iron. The 340 grammes loss in milling the retort is due to the amalgam not being thoroughly clean of sands, the ash from the paper used in retort and pieces of luting, and lime from the white-washing of the retort, also quicksilver, which is always difficult to drive completely out of the retort. Of course a loss of gold occurs, but this loss is very little.

The practice at Los Reyes is to clean up a battery of ten stamps every thirty days. The feed for one of the mortars is stopped, and the level of the inside pulp run down as much as possible, the five stamps are then hung up, screen and front inside plate are taken out, and the butts or headings removed and run through the other mortar of the battery. If the dies are still high enough to last another run, they are allowed to remain, the butts surrounding them being removed and run through, along with the upper ones. When all butts are passed through the mortar of the still running five stamps, the feed in this mortar is stopped and the pulp inside stamped down as much as possible, then the stamps are hung up.

The inside plates are placed on the plate tables and the amalgam, which is generally very hard, removed with chisels, a carpenter's 1½" chisel being excellent for this purpose. Meanwhile the butts in the last mortar to be cleaned are collected in tubs. These butts have a good sprinkling of quicksilver added, and are washed with water on the top of the outside plates. The amalgam in the butts is nearly all collected in this way, but as a precaution, all butts and cleanings from the amalgam and plates are collected in pans and not allowed to go over into the tailing pits, but subjected to a thorough panning in a gold pan, to recover amalgam and put through the mill again. After all the amalgam has been collected from inside plates and mortars, butts

and outside plates, the larger lumps are ground in a mortar till all is fairly fine and granular, with the appearance of test lead. Charges of this amalgam are then put in a gold pan and enough quicksilver added to make the mass like stiff dough, a jet of water is run into the pan, the mass is stirred, and in this way considerable of the sands, sulphides and metallic iron is removed, the large pieces of the latter being removed with a magnet. When most of the sand has disappeared the amalgam is dumped on one of the outside plates and rolled as one would roll dough, water being added to carry off the fine sands which are liberated by this treatment. Care must, however, be taken that the amalgam be not too thin or it will run down the plates.

After this washing and rolling the amalgam is clean and bright, but is subjected to a regrinding in a wedgewood mortar with enough mercury to make it into a thin paste, and a stiff emulsion of lime. After grinding, the lime emulsion is removed with a piece of sponge, some rather dirty amalgam being removed along with the lime, but the lime and amalgam are carefully washed off the sponge into a gold pan. The amalgam left in the mortar is now considered clean, and is pressed through wet chamois leather into balls of from two to three pounds in weight. After all amalgam has been treated with the lime emulsion the cleanings are panned down and subjected to a thorough grinding in the pan itself with a hardwood muller, and again in a mortar, till quite bright, when it is passed through the chamois.

It will be noted that all cleaning of amalgam is done over amalgamated plates, all washings being collected and subjected to further pannings, the values being collected and the sands and dirt passed through the mill again. This method of cleaning on top of the plate tables, which are high enough to make work comfortable, practically assures a minimum of loss in both quick and amalgam. In the record shown in the 30-kilo clean up, work was started at 6 a.m., and by 11 a.m. all amalgam was cleaned and ready for the retort.

The amalgam, which is in the shape of balls ranging from 400 grammes to 1,500 grammes in weight, is wrapped in newspaper, each ball being wrapped separately, and placed in the retort which has been white-washed inside with lime. The charge must never be greater than three-quarters of the retort. The cover of the retort is

then luted on with a stiff mixture of wood ashes and salt. Fine slimes answer the purpose, but not as well as the ash. When the water connections of the condenser are made a slow pine charcoal and wood fire is started till the quick begins to retort over. As soon as the quick runs freely the fire is increased and the retort brought up to a dull heat, and when the quick ceases to collect below the condenser the cover is taken off and the retort allowed to stand in the furnace for a few minutes to allow any vapour of mercury and other gases to escape. On removing the retort, the spongy balls of bullion are removed before cooling with a pair of tongs and placed on an iron plate to cool. The advantage of wrapping each ball in newspaper is readily seen, as the paper forms films of ash between each mass, so that no fusing together takes place, and does away breaking the retort gold with chisels.

The gold is melted in a No. 12 Dixon graphite crucible, with a lump of borax flux. When all the gold has been added and the surface of the charge is still, a mixture of soda bicarbonate and nitre is added to take up into the slag any iron matte that may be present. As soon as the whole charge is at a proper heat, the gold is poured into a hot mould well greased with lard oil, and when cool the bar is removed and the slag broken off with a sharp blow of a hammer. No skimming is done, the slag being always brittle and easily removed, leaving the bar quite clean and bright, with no staining or film of iron matter on its surface. The charge of nitre and soda brings about this result. The bars are then stamped and top and bottom samples taken for assay. These samples weigh about $\frac{1}{2}$ gramme each.

A large cyanide plant is being installed to treat the accumulated tailings both from the present mill and from the arrastre plant used in the old days to treat the ore. This plant promises to be very interesting as all old tailings have to be reground to get rid of acids and salts due to oxidization, and the whole treated in slime tanks 22 feet by 6 feet. Air agitation and decantation will be used. The fresh mill tailings, however, will run direct through classifiers, the sands being treated by percolation, the slimes in the slimes plant. An accumulation of concentrates will be roasted first and treated by percolation. In a few months time Los Reyes will be equipped with mill and plant that is confidently expected to save over 95 per cent. of the values in the ore.

CONCRETE CRIBWORK.

A. E. Gibson, B.A.Sc.

In the building up of any new country the settler and the engineer are compelled to use timber almost entirely as their material for construction. Then as the country develops the engineer is forced by the scarcity of timber to resort to other materials, and thus in place of the settler's log cabin, we find houses erected out of brick, stone and steel; in place of timber and culverts, we have steel bridges and concrete culverts; and it is my intention to occupy your time for a little while this afternoon in discussing a substitute for timber in the construction of cribwork.

If timber is completely immersed in water, it will last the best of a lifetime, but allow it to be immersed one day and the next day exposed to the atmosphere, and the life of such timber will not exceed ten years under the most favorable circumstances, so that the most vital part of all kinds of cribwork is that portion at and near the water line. Our discussion now has narrowed down to finding some material for the superstructure which will not be deteriorated by the outside elements.

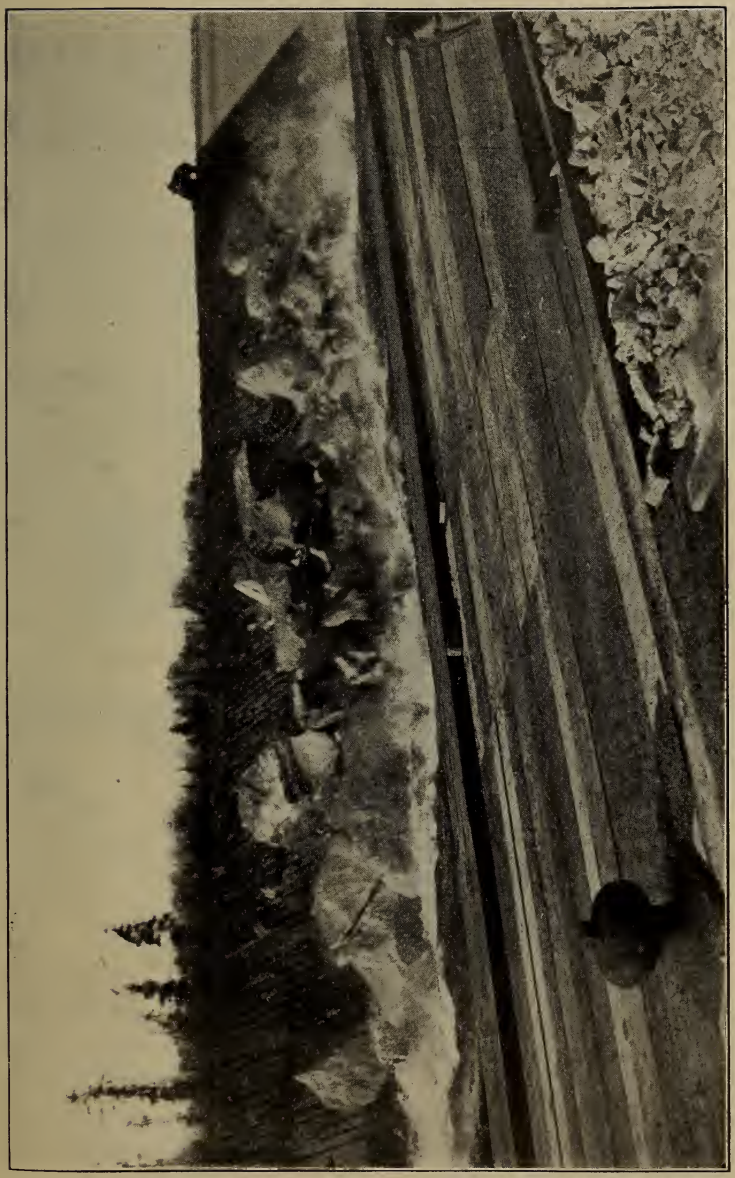
At the present time, Messrs. Davis, Haney and Miller are building a dock at Depot Harbor, Ont., for the Dominion Government, which seems to contain a solution to this problem. The original contract called for timber to be used in the superstructure, but last winter, J. W. Fraser, the Government Engineer who was in charge of the work, conceived a new idea in constructing the superstructure, and the Government looked upon it so favorably that they decided to adopt it in the Depot Harbor work. I might add he has the idea patented in both Canada and the United States, and patents throughout the world have been applied for.

I regret very much to have to state that Mr. Fraser was drowned last summer in the St. Lawrence River by the upsetting of a sail boat.

As an evidence to show what the Government thought of his scheme they have already let large contracts for breakwaters at Port Colborne, Port Stanley and Rondeau, using his system entirely for the superstructure.

Before proceeding with the description of this system, I will endeavor to give you a brief outline of the character of the foundation and substructure.

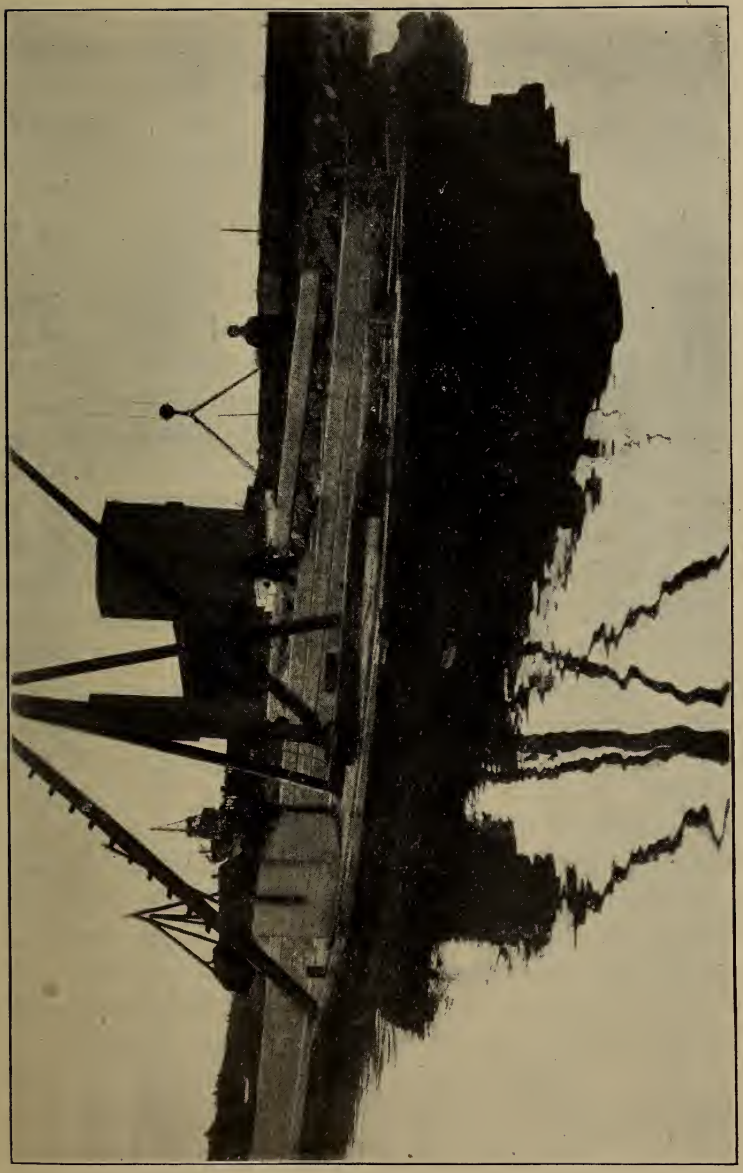
The dock is 400 feet long, 150 feet wide and is composed of 5 cribs: the two cribs nearest the shore being 200 feet long, the two abutting them 170 feet long, the one across the end 150 feet long, and all of them 30 feet wide. The soundings for cribs Nos. 1 and 2 ran from about three feet nearest the shore to 13 feet at the other ends; and the rock soundings ran from about 16 feet to 24 feet. Seats were dredged for these cribs so that they would have a firm foundation, and the bottoms of them were constructed to conform to the shape of the rock bottom. The mud soundings for the remaining cribs ran from about 14 feet to 20 feet, and the rock soundings from 24 feet to about 45 feet; and since this bottom was composed very largely of a fine silt, it was necessary to construct a more substantial foundation. This was accomplished by dumping large stones, many of them weighing 6 and 8 tons, and levelling the top of this foundation to an elevation of about 24 feet below low water. A very novel and original scheme was adopted in dumping this stone. Two scows 100 feet long, 25 feet wide and 8 feet high, were constructed, having their decks sheeted with steel strips running crosswise. They had longitudinal water-tight partitions constructed in their holds running the full length of the scows, to prevent water running from one side to the other. Three orifices with valves were placed on one side and near the bottom of the scow, and by means of levers, these valves were regulated on deck. After placing the scow in the actual position where the stone was to be dumped, which was accomplished by passing lines from each corner of the scow to buoys anchored at suitable distances, the valves were opened, allowing



Stone Scow in the Act of Dumping.

water to run in through the orifices and thus cant the scow. As the water increased, the scow commenced to cant, until the angle became sufficient to allow the stone to slide off. The decks were greased to reduce friction to a minimum, and we found it advisable to pile all the large stones on the high side so that when they slid, they simply swept the decks. After the scow had been placed, it took from 40 to 60 seconds to dump a load, and as the water could be pumped out in about an hour, you will readily understand what a time and labour-saver it was. I might add that the scows were made exceptionally strong, for this sliding and rolling of rocks would sink any ordinary scow.

Having now secured suitable seats for the cribs to rest on, they were sunk. This was accomplished by placing timbers on top of the crib in three places, at each end and in the centre. Sufficient stones were now piled on top of these timbers to sink the crib to its final position, care being exercised to sink it as level as possible. A diver was now sent down to determine definitely if the crib had a firm bearing, and was not resting merely on a few high stones. This being done, and having lined the crib up, which operation was done with a transit, the pockets were filled with stone. The important point to observe in filling a crib, is not to load any one place too heavily, less the crib will be tilted and therefore put out of line, but loaded uniformly. Quarry waste was used to fill the bottoms of the pockets for a height of four or five feet, and after this height was reached, larger stones were mixed in with the waste. The cribs had been constructed previous to the alteration of the superstructure, which required them to be levelled to an elevation of one foot above extreme low water, and a continuous superstructure built from this elevation; but with this new style of superstructure, it was required to level the cribs to extreme low water and carry the superstructure up from here. This involved the tearing off of a couple of the top courses, and this work was made exceptionally difficult because of the water remaining about two feet above low water all summer. However, with the aid of high rubber boots this was accomplished. The superstructure was built seven feet above extreme low water and had an average width of ten and a half



View of Dock Constructed of Reinforced Concrete Members.

feet. It was constructed of reinforced concrete members 12″ by 12″ square and running from 20 to 9½ feet in length, the members being firmly secured together by iron rods. It was thought advisable to make the moulds for casting these members as strong as possible, for any warping of the moulds would cause the members to assume the same shape, and therefore would not lay level one on the other. The company had a quantity of 12″ by 12″ timber on hand and it was decided to utilize this in constructing the moulds. After levelling a firm foundation, these timbers were laid side by side to form the bottoms of the moulds. On top of these timbers and parallel to them, 12″ by 12″ by 22 feet timbers were laid one foot apart, the intervening spaces forming the moulds. The sides of some of the moulds were also constructed of 4″ timbers, but they did not give as good satisfaction as the 12″ by 12″ timber, for a timber 4″ thick and 22 feet long is bound to warp if exposed to the hot rays of the sun for any length of time. The side of the mould representing the face of the member was planed to insure a smooth surface. End pieces of one-inch lumber were now put in to make the members conform to their required lengths and forms. One-inch fillets were placed in the two outside corners of the moulds of the face members to give them a bevelled edge in place of a sharp one.

The concrete was composed of one part Portland cement, two parts sand and four parts broken stone turned and mixed in the regular way.

The members were reinforced with four iron rods located about two inches from each corner and long enough to extend the full length of the members and form a hook at both ends with a radius of 6 inches. The idea in forming the hook being to increase the grip of the concrete on the iron when the adhesion, on account of the cement being green, was not very great, and thus the members could be lifted sooner after being cast than they otherwise could. The face members had two ½″ round iron rods near the outside, and two ¾″ round iron rods near the inside. A horizontal layer of concrete was first put in the mould and the first two rods inserted, then another layer of concrete with the other two rods on top, and lastly another layer of concrete. The concrete was well tamped especially around the side representing

the face of the member, to insure a smooth uniform face. The outside members, because of their being laid close faced, were finished on top with concrete mortar composed of one part cement and two parts sand. The corner members had iron plates, $\frac{1}{2}''$ x 12″ x 33″, set in them when being cast and secured by four $\frac{3}{4}''$ x 10″ anchor bolts. These corner members were built up by the side and end members overlapping the corner alternately. The longitudinal and cross ties were reinforced with four $\frac{1}{2}''$ round iron rods extending their full length and returning by hooks as with the face members. They were cast in a similar manner to the face members, but it was not necessary to exercise such care in finishing their tops. To make the holes in the members for receiving the iron rods and lifting holes, wooden plugs were used. These plugs were tapered from $2\frac{3}{4}''$ square at the top, to $2\frac{1}{2}''$ square at the bottom, to insure their being removed without tearing down the concrete. The concrete was allowed to set a couple of hours before these plugs were removed. Each plug had a nail projecting about $\frac{3}{4}''$ at the bottom to hold it in its place, and an eye in the top by which it could be withdrawn. During the extreme hot weather the members were daily sprinkled with water and protected from the direct rays of the sun by tarpaulins.

We have now reached, by those who strenuously opposed the scheme, its most serious objection, and an objection which they claimed would make the system impracticable. They set forth the plea that a concrete member 20 feet long would have to set probably a month before it would be able to be removed, but we demonstrated that such a belief had no foundation, for the majority of them were lifted from their moulds in five days, and thus the same moulds could be refilled quite a number of times in the one season. After they were removed from the moulds they were arranged in piles, spaces being left to facilitate their drying.

The first member was securely fastened every five feet to the substructure by drift bolts 1″ in diameter and 27″ long. Now in timber cribwork the ties are mortised into two face timbers, the bottom one being called the receiving stick and the upper one the covering stick; but with this system the ties are placed on top of the lower members

and the spaces between the tie heads are filled in with short concrete members. These tie heads were securely fastened to the face members by 1″ round iron rods running through the heads from top to bottom of the superstructure. Two iron rods were used between the tie heads to bind the face members well together, while the back ends of the ties were bolted to the longitudinals. Before these rods were inserted, grout was poured into the holes and then the iron rods were driven down.

The chambers or pockets were now filled with hand-packed stone, care being taken that the stone filling had a solid and uniform bearing on the face members. This stone filling was covered with a layer of concrete 8″ thick, which bound the top well together.

Having now given you a brief outline of the work, I will endeavor to compare its relative merits with that of timber cribwork and solid concrete work.

It is no new idea to use stone and cement to lessen the cost of maintenance, but the primary cost has been so excessive that the interest charges have been as much as the charges for repairs and maintenance in a timber structure. Therefore such works have been almost prohibited in a young country such as ours. Again the unsatisfactory timber structure is yearly becoming more expensive and difficult of construction owing to the increasing scarcity of dimension timber, therefore it is evident that a new departure must be made in the construction of reasonably cheap and permanent docks and wharfs.

The cost of building cribwork superstructures and other works with this system may be reduced considerably below the actual present cost of building timber cribwork with stone filling, by filling the chambers with earth instead of stone, as is done at present with timber work.

In such a case it would be advisable to build the entire walls of the work perfectly tight in order to protect the filling against the wash of water. This could be done by placing a string of oakum or other packing between the outer layers of pieces, when being laid one on top of the other. It would also be advisable to put horizontal tie

rods in the crib, since the earth filling would have a greater lateral pressure than stone filling.

Now it may be claimed that timber cribwork in its present form could also be filled with earth in order to reduce its first cost; but the very fact that the superstructure of timber cribwork is of a perishable nature, forbids the use of earth for filling, as the decay of the timber weakens the structure, when it is easily damaged by the elements, and in that condition the cribbing could not hold the earth filling against the eroding effects of water. Besides earth filling would accelerate the decay of the face members of superstructures.

It may appear at first sight to some that the substitution of earth for stone, for filling or ballasting cribwork, would reduce the weight of the structure, thereby endangering its stability if the work be exposed to storms, or the pressure of any kind unless its bulk be increased to meet the deficiency.

Following is the average weight of a cubic foot of any material that may be used for filling:

Boulders from ½ ft. to 3 ft. in diam	100 to 120 lbs.
Clay, moderately packed	100 to 110 lbs.
Earth, common loam, wet, well pressed	110 to 120 lbs.
Gneiss, run of quarry up to 4 ft. diam	90 to 100 lbs.
Gravel or sand, moist	115 to 130 lbs.
Limestone, quarried in irregular fragments	90 to 100 lbs.
Mud, wet, moderately pressed	110 to 130 lbs.

From the above it may be seen that gravel or sand, earth, mud and clay weigh generally more than the ordinary stone ballast on account of the large voids that are unavoidable in the latter.

Earth would form a very compact filling, giving a degree of elasticity that would have the effect of deadening any blow the structure might receive. Under this system too, the substitution of concrete members for timber ones, would add to the weight of the structure and help to permit of the use of other material for filling even lighter than those above named, such as ashes, broken brick, &c.

It was contended by some that a dock constructed after this system would not be as strong as a similar one constructed of wooden

members, but Mr. Fraser contended it would be stronger and have the additional advantage of increasing in strength with age, while the one constructed of timber would decrease. It is not probable that it would resist the blow of a large vessel running into it head on, but it must be borne in mind that a dock is a landing place for boats and not a fortress. Indeed it is a question whether or not it is advisable to have a dock too strong, for quite frequently it is more economical to repair the dock than it is the boat. However, even should cribwork constructed after this system, be damaged, it has almost equal advantages with a timber dock of being repaired.

Another very important advantage that it possesses over the present timber cribwork, is that it is absolutely fireproof. This advantage, even if for no other, ought to commend itself very favorably with the public.

However, as yet the system is but in its infancy and little known by the majority of engineers; but I am firmly of the opinion that in it we have a permanent and moderately cheap system for all kinds of cribwork.

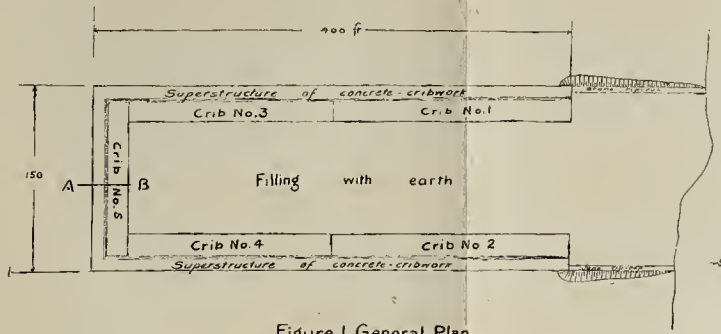


Figure.1. General Plan.
Scale: 50ft=1inch.

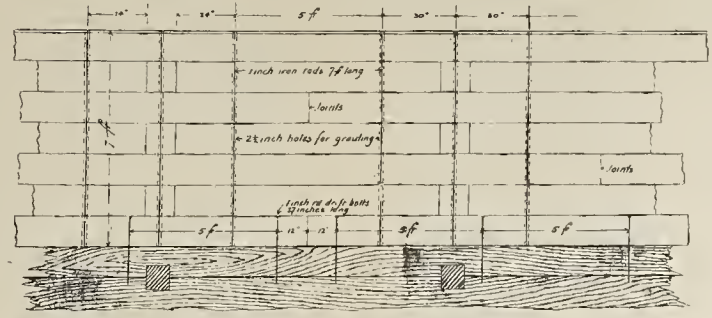


Fig 2. Port elevation of concrete-cribwork
Scale 2'f = 1 inch

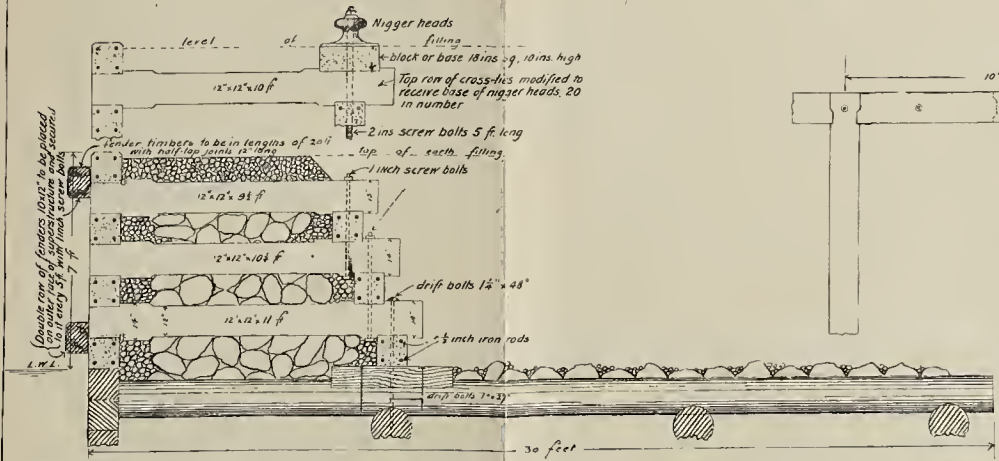

Nigger heads
level of filling
block or base 18ins sq. 10ins. high
Top row of cross-ties modified to receive base of nigger heads. 20 in number
12"x12"x10'f
2 ins screw bolts 5 ft long
Fender timbers to be in lengths of 20'f with half lap joints 12" long
top of earth filling
1 inch screw bolts
12"x12"x 9½'f
12"x12"x10½'f
drift bolts 1¼"x 48"
12"x12"x11'f
⅞ inch iron rods
drift bolts 1"x3'
Double row of fenders 10x12" to be placed on outer face of superstructure and secured every 5'f with 1 inch screw bolts
L.W.L
30 feet

Fig 3 Cross Section at A-B
Scale. 2'f = 1inch

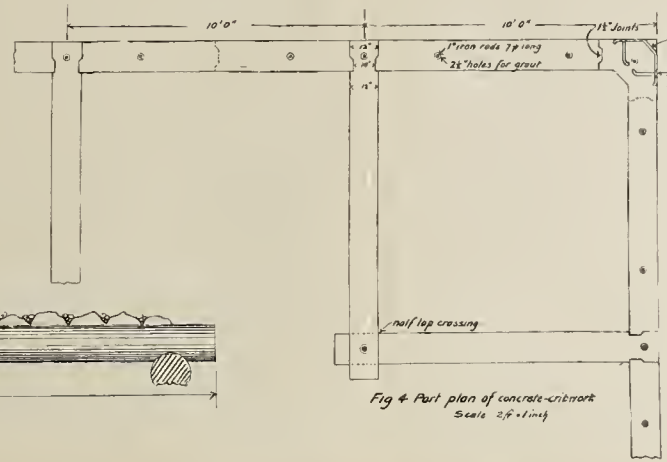


Fig 4 Part plan of concrete-cribwork
Scale 2'f = 1 inch

Fred R Mueller
Depot Harbour 1904

WORKING DRAWINGS OF THE DOCK DESCRIBED HEREWITH

THE VALUE OF FOREST.

J. Clarke,
Director of Forestry for Ontario.

The maintenance of a forest cover on its non-agricultural lands for the production of timber and the conservation of water, is one of the greatest national problems which a country can undertake. The importance of the problem naturally increases with the area concerned, and inasmuch as Canada has fully 300,000,000 acres of such rough lands, it will be appreciated that it is a problem of first importance in the national life. The country which has an abundance of timber and unlimited water power will presently take a very much more important place in the family of nations as a producer and as a manufacturer, and Canada has very exceptional opportunities of taking first rank in both regards. If she excels in the one she will excel in the other. If she fails in the one she must fail in the other, for the destruction of forests goes hand in hand with the loss of stream flow for transportation, for power or for irrigation.

I should like to say a word to prove that it is worth while, from the standpoint of timber production alone, to maintain this FOREST COVER. In other words, to prove that it will pay, in this connection I want to emphasize one fact—that the recent tremendous advance in the value of stumpage is a perfectly normal and absolutely inevitable result of modern commercial conditions of supply and demand. The fact is that, as man becomes civilized, he needs much wood, and the higher his civilization becomes the larger his needs. Then, too, the more highly civilized countries are almost, without exception, increasing rapidly in population. On the other hand, the areas producing the kinds of wood which are in most demand are rapidly being stripped of their product, and little or no care is being taken to ensure another crop. This latter proposition needs no proof. In proof of

the increasing use of wood by civilized man, the consumption of wood in the United Kingdom, where practically all the timber is imported, and is consequently used with economy, will serve as a fair illustration.

It should be remembered that the United Kingdom is an enormous producer of steel and cement, and their use in substituting wood in construction is very much greater than in Canada or the United States. The consumption of hewn, sawn and split timber showed an increase of 80 per cent. during the 15 years ending 1900. The per capita consumption increased during this period exactly 60 per cent. The consumption of the valuable furniture woods—not included in the above—increased about 100 per cent., while the per capita consumption of wood pulp in its various forms showed the remarkable increase of 310 per cent. in the 15 years, the figures being 9.5 lbs. per man in 1886, and 30 lbs. in 1900. The per capita consumption of timber has likewise increased in practically every country in Europe. Time forbids details, but I might mention that Germany, where 24 per cent. of the empire is in forest, and where the most extensive forest management in the world is practised, their timber product, while greatly increased, has failed utterly to keep pace with Germany's needs. Germany was an exporting country up till 1863, when her imports for the first time were equal to her exports. Since then her imports have steadily increased, and in 1900 it took $70,000,000 to pay for the excess of imports over exports.

Near home we find the same story, but with even greater emphasis. The United States' per capita consumption of 160 feet board measure, in 1850, has steadily grown from decade to decade, until in 1900 it reached 460 feet. The total consumption has grown at a much more rapid rate, for the increase of population has been very great. In 1850, between three and four billion feet supplied the needs of the nation, and in 1900 it required more than thirty-five billion feet. The rapidly advancing prices of the last decade, aggregating fully 100 per cent., have failed to materially check this tremendous consumption, for the latest statistics indicate a small but substantial increase in the per capita consumption.

THE CANADIAN SITUATION.

While we in Canada are interested in the outlook for a market for our surplus stocks, the insuring of an adequate supply of timber for the development of our own country is the matter of greatest importance to us. Canada is on the threshold of a great national development. Aside from the character of the population of the future, nothing will contribute more largely to our national advancement than an abundant supply of timber. We have not the data at hand to determine our present per capita consumption, but we may safely assume that the tendency is similar to that in other civilized nations.

The conservation of water is secondary perhaps to the production of timber, but its importance can hardly be overestimated. The keynote of worth in stream flow, whether for navigation, power or irrigation, is SUSTAINED FLOW. The forest is the great regulator of the flow of streams. The rainfall of any country returns to the air and the ocean in four ways—by evaporation and transpiration, called the "fly-off," and by surface run-off and seepage run-off, forming the stream flow.

The evaporation and transpiration of moisture on forested areas is well known to be much less in temperate climates than from non-forested areas. The less that is returned to the air, the greater the amount left for stream flow. The greatest value of the forest, however, is in decreasing the surface run-off, and in increasing the seepage run-off, by which latter is meant that portion of the rainfall which enters the soil and reappears at lower levels in the form of springs. The checking of the surface run-off is due to the rapidity with which forest soils absorb the water as it falls, the ease with which it percolates downward, and the obstruction presented to quick flow over the surface by leaves, twigs, moss, etc., giving the water which does not at once enter the soil more time to penetrate as it moves slowly towards lower levels. A further advantage of forest cover in water conservation is the slowness with which the snow melts in the evergreen forest as compared with denuded hillsides, thus preventing disastrous floods

in early spring, by distributing the flow from the melting snows over weeks instead of days. On the eastern slope of the Rocky Mountains the forest cover has still another and very important function in checking the sweep of the dry Chinook winds, which evaporate the snow so quickly on exposed areas. It has been found that the rate of evaporation from snow surfaces under these conditions, is at least several times as rapid as that from a water surface under similar circumstances. A snow-fall of a foot in depth may entirely disappear on these hillsides when the forest is wanting, in two or three days, without even wetting the soil.

There is another feature of forest conservation which appeals to most citizens quite as strongly as the provision for a future supply of timber, or the conservation of water for transportation, power, or irrigation. I refer to the income which the different provinces and the Dominion may hope to receive from their forest lands in the form of cash for stumpage or for power developed. This revenue, already large, is capable of being very greatly increased. In Ontario alone there are at least 50,000,000 acres of non-agricultural lands which should be retained as a timber-producing area in perpetuity. At present stumpage rates, the wealth here represented is very great. There is not only every probability, but a certainty, that in the future the value of this stumpage will be much higher. I have not the slightest doubt but that the value of the annual growth of timber on these 50,000,000 acres will exceed, by the year 1925, $20,000,000, if rational methods of lumbering the present stands be adopted, and all possible measures be taken to reduce the fire danger. On the other hand, we have in our neighbor State, Michigan, an example of what may become of pineries, once of greater value than any we now possess, when reckless lumbering goes hand-in-hand with fire. Vast areas, once cutting as high as 20,000,000 per sq. mile, and capable of again producing the finest pine in the world, now lie absolutely waste and can only be reclaimed at a cost which, in the aggregate, would greatly exceed the total revenues received in the past by the State for the exploitation of its lands. All this because they who disposed of these lands did not know that at a trifling cost in reserving seed trees, and a comparatively small outlay for fire protection, these lands could

have been reforested by natural seeding, even more efficiently than by the hand of man. Unfortunately they learned too late. Their forests are gone—over very large areas of non-agricultural lands absolutely gone—and the only restoration now practicable is by the slow and expensive process of planting.

In a rough and rocky country, such as much of Canada's forest lands are, such lumbering and fire as was the rule on the pine plains of Michigan would be even more disastrous, for often the soils on these rocky hillsides are so largely composed of organic matter that when burned over in a very dry time the soil itself becomes destroyed, and the possibility of a future forest is removed. When this occurs, the natural resources of the country are by so much diminished. Large areas of Canadian woodlands have thus been destroyed. At the present time this kind of destruction goes on apace on the eastern slope of the Rocky Mountains. Should this continue unchecked, not only will large areas of the mountain slopes be rendered worthless, but the amount of water available for irrigation in Southern Alberta will be proportionately decreased. It has been estimated that if all the waters at present flowing from this slope were utilized for irrigation purposes, not more than 15 per cent. of the lands needing the water would be supplied. Any reduction in the amount of water available means fewer homes on the plains adjacent.

AN OCCURRENCE OF COBALT-NICKEL ARSENIDES AND THEIR SOLUBILITY IN AMMONIA.

G. S. Hanes, '03.

Rich deposits of cobalt-nickel silver ores were discovered at Cobalt in the fall of 1903; but as these minerals were not very well known to the prospectors, the value of the deposits was probably underestimated for some time. However the developments which rapidly followed have proved without a doutbt the existence of some comparatively large deposits of cobalt-nickel-silver ores.

Cobalt is a post office on the Temiscaming and Northern Ontario Railway (the Government line which is under construction from North Bay Junction to a point near Lake Abitibi), and is about five miles south of Haileyburg.

The first discovery of minerals was made in a rock cut on the railway near the north end of Cobalt Lake, at the edge of a swamp, and the two shafts which have been sunk on the vein are right along side the railway.

During the spring and summer of 1904, considerable prospecting was done, with the result that several other valuable properties were located. The veins all appear to be vertical and cut through the formations known as slates and slate conglomerates or breccia conglomerates. These fragmental rocks have been formed from the weathering of the diabase which outcrops in several parts of the district.

These outcroppings show a very much weathered surface, and the diabase rocks are, at first, hard to distinguish from the slate conglomerates and Huronian slates.

Where the diabase had any troughs or valleys, these have been filled in with the slates and conglomerates. In some places the slates

may have considerable depth, especially over the centre of a trough, but will get thinner as the outcroppings of diabase are approached.

The depth of the slates will probably have an important bearing on the depth of the veins, as the veins may not penetrate the igneous diabase rocks beneath.

The fragmental rocks, which overlie the harder diabase, have probably had wider fissures opened up in them, than in the diabase beneath, as the former are much softer than the latter; thus the veins when filled in with ores are generally supposed to only go down as far as the diabase.

In one case already the vein remained a uniform width while passing through the slates, but when sixty or sixty-five feet of shaft had been sunk, diabase was encountered, and the vein was practically lost, as only a few narrow veinlets continued down. In another case the shaft has reached a depth of 90 feet or more, in the slates, and good ore is still obtained, the values remaining practically uniform for this depth.

In a third case, however, native silver has been found in small veins in the diabase rocks at the surface, although the veins do not appear to have any very great depth and are probably shallow. In general, however, it still remains to be determined whether these veins penetrate the igneous diabase rocks beneath to such an extent that they may be worked profitably.

The veins cut the slates nearly vertically, and are all widths up to six feet. The veins may be divided into two parts, one very rich and concentrated, the other containing more or less gangue material. The rich concentrated portion may be as wide as sixteen inches, and consist of smaltite, niccolite, native silver, along with the oxidized and weathered products, and generally some calcite.

The following is a list of minerals which have been found in these veins:

Cobalt Ores.	*Nickel Ores.*	*Silver Ores.*
Smaltite,	Niccolite,	Native Silver,
Erythrite,	Chloanthite,	Dyscrasite.
Safflorite,	Annabergite,	
Heterogenite.	Garnierite.	

All the veins appear to carry cobalt and nickel, and all but one have silver values of varying amounts.

The ore, when examined, has a massive appearance and rather a dark grey color, where it is not coated with erythrite (cobalt bloom). Occasionally a very large mass of the bronze colored niccolite gives a little variety to its color. In general the niccolite has crystallized out first in small bronze colored crystals, and the smaltite has formed small radiating globular masses around these crystals as a centre, thus giving the ore a somewhat mottled grey appearance. The silver occurs in plates, threads, etc., and is scattered here and there all through the vein, sometimes in very large masses weighing several pounds. On the surface this ore has been weathered, and the outcroppings generally show the beautiful pink mineral erythrite and the green mineral annabergite, thus making prospecting very easy. However, where these surfaces have been subjected to the action of running water, etc., the cobalt bloom has been washed off, and it is extremely difficult to distinguish the surface of the vein from the surrounding slates or diabase rocks.

The gangue material consists of calcite and generally is in comparatively small quantities. The calcite and the ores are mixed irregularly, and do not appear to have any definite arrangement.

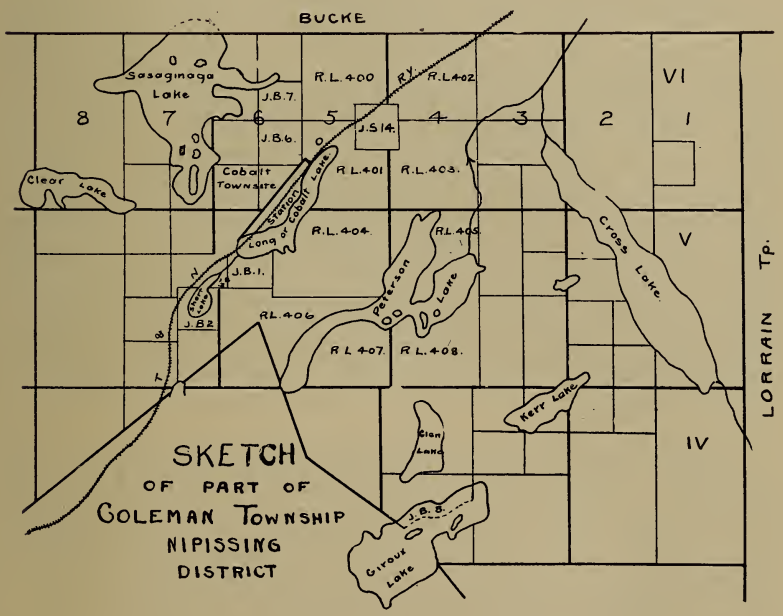
As the surface is pretty well covered with moss and soil, and well wooded with large timber, the horizontal extent of the veins is hard to determine, although two or three have been uncovered or traced for four or five hundred feet.

The strike of the veins is not very regular, as it may vary considerably. The general strike is east and west, while some are north-west and south-east, and others north-east and south-west.

The first discovery of any importance was made on location J. S. 14. The vein runs north-east and south-west, and has a total width of about 6 feet in places. However, a rich streak from four to sixteen inches wide occurs, which is very nearly pure smaltite and niccolite, with large quantities of silver. Two shafts are being sunk; the deepest being about 90 feet. These two shafts are about 200 feet apart. Large masses of native silver were obtained near the surface,

one piece of very nearly pure silver weighing 400 pounds. This ore averages from $1,000 to $2,000 per ton, and five or six carloads of rich concentrated ore has been mined up to the present time, all of which has been obtained in the sinking of the shafts alone.

On location J. B. 7, near the south side and parallel to it there is a cobalt-nickel-silver vein which has a rick streak of concentrated ores about ten to sixteen inches wide. The shaft is about 65 feet deep, and three carloads of this rich ore has been obtained from it.



The first carload sold for $37,500. This vein has been uncovered for a distance of three or four hundred feet.

A few hundred feet to the south of this vein, in location J. B. 6, another vein, similar to the one mentioned above, has been found, but as yet not much work has been done on it.

On location R. L. 404, a vein of cobalt arsenide is being worked which has a strike north-west and south-east, and occurs on a hill about 70 feet above the level of Cobalt Lake. The vein has about

sixteen inches in width of concentrated ore, and according to assay, averages from 16 to 19% cobalt, and 4 to 7% nickel, with about 6% iron, and from 60 to 69% arsenic. About 300 tons of this ore has been mined during the past summer, and during December of 1904, was piled up in a log building near the vein. This ore is sold for 65c. per lb. for the cobalt alone. That makes it worth $1,300 per ton for cobalt, and is increased considerably when the nickel and arsenic values are added.

On location J. B. 1, a vein is being worked which has an east and west strike. It is only a few feet away from the south end of Cobalt Lake, and near an outcropping of diabase. The shaft, which is being sunk, has reached a depth of about forty feet, and very rich ore is being obtained. Assays show the following values: Silver, 11%; cobalt, 15%; nickel, 5.5%; arsenic, 49.6%; sulphur, 2%. This ore, in general, has averaged $1 per pound, or $2,000 per ton. Two or three carloads have been shipped. The walls of the vein have small cracks and fissures filled in with native silver, and the gravel and weathered product which forms the lake shore, on being assayed for silver, gave 750 ounces of silver per ton, and also has good values in nickel and cobalt. There are several carloads of this ready to be packed and shipped.

A small silver vein occurs on location R. L. 406, with an east and west strike. It has a width of from four to eight inches, but although it is very narrow, still it is a very interesting one; the vein appears to be composed of native silver cemented together with erythrite and other decomposed minerals. Some large masses weighing 40 or 50 pounds were taken out, which yielded about 80% silver.

A specimen of this weathered ore, which appeared to contain less silver than most of the samples collected, was found to contain about 16% silver, 4% cobalt, and small quantities of nickel and arsenic. Three other weathered samples gave the following values: Silver, 23 to 27%; cobalt, 2 to 8%; nickel, 1 to 5%; arsenic, 13 to 18%, while the average value of silver was found to be about $5,200 per ton. This vein cuts into a cliff 60 or 70 feet high, and a tunnel has been driven in for about 80 feet.

Other rich silver veins have been found along the south shore of Kerr Lake, but little work has been done, as they were only discovered late last fall.

Up to the present time, twelve or fourteen carloads of these rich ores have been shipped, and over $300,000 has been realized on them. So there is no doubt but what this is a mining district which will ship these valuable ores for some years to come, and its richness cannot be questioned. The value of the mines at present can hardly be realized, as the shafts alone which have been sunk have averaged about $1,000 worth of ores per foot in depth, while the cost of sinking is comparatively small.

However, if these mines are developed too rapidly there will be a danger of the supply of cobalt exceeding the demand and the prices would therefore probably decrease in proportion. As yet no refining plants have been established in Ontario, and all the ore has been shipped to the United States for treatment. These ores being remarkably rich, and occurring in comparatively large quantities, new methods of refining may be used; in fact, since these ore bodies are unique as to composition and values, it is probable that some new method of treatment will be devised, which will separate the minerals to the best advantage.

The writer has been carrying on research work in connection with a new method for treating these ores. It has been found that cobalt-nickel arsenides are soluble in ammonia under certain conditions, and the investigations have been along that line. The experiments have been entirely satisfactory, although at first it seemed that no such reaction would take place. The writer has taken the trouble to study a great many books on chemistry, and has not been able to find anything bearing on the solubility of cobalt-nickel arsenides or sulphides in ammonia.

The whole process is based on the action of oxygen of the air on the cobalt-nickel arsenides in the presence of ammonia. The chemical change appears to depend on the fact that these arsenides and sulphides in the presence of ammonia and oxygen, are converted into

hydroxides, which are soluble in ammonia. The oxygen of the air replaces the sulphur or arsenic, and the oxides so formed immediately become hydroxides in the presence of ammonia; and an excess of ammonia will readily dissolve these hydroxides. The nickel and cobalt can be obtained by an electrolitic process by which each metal can be deposited separately, or the solution, if evaporated, will give the hydroxides or oxides of the metals.

A partial separation of the nickel and cobalt may be carried on during the process, as the nickel arsenides are more soluble than the cobalt arsenides, and, therefore, the nickel is mostly dissolved up before the cobalt commences to go into solution.

In this method of treatment the ore requires to be finely pulverized. This pulverizing is necessary, in any case, in these ores from cobalt, as the silver occurs in masses, thin plates, threads, etc., and is separated out by screening. The ore may be considered fine enough when it will pass through a 120-mesh screen.

The ore is crushed in at least two stages: 1st, it is crushed to 30 or 40-mesh and screened; this removes the large masses, plates, etc., of silver; the screened ores are then pulverized to 120-mesh and again screened. This second screening removes all the fine silver which occurs as small flakes. If any silver should now pass through, it will be obtained from the tailings after the treatment of the ores with ammonia.

This very finely pulverized ore is now placed in a cylinder, or special apparatus with a filter bottom, so arranged that air may be blown up through the mass. A solution of ammonia is run in so as to cover the ore and completely saturate it, then when the current of air is forced up through it, the ores commence to go into solution.

The filter bottom is arranged in such a way that the air under pressure may penetrate it at several points and pass up through the pulp. The air in escaping will carry off some of the ammonia with it; and if this air is passed through water, the water will absorb the ammonia and thus prevent any loss. When the water has become sufficiently saturated it may be used for treating more ore, or it may be heated and the ammonia obtained in a more concentrated solution.

The solubility of the ore depends on the strength of the solution of ammonia, also on the amount of air passed through the pulp. The strength of the ammonia solution used has been one part ammonia Sp. Gr. 880 to two parts water, although experiments have shown that if the strength of the solution is increased the rate of solubility will be increased also.

Air under pressure is required so that it may readily force its way up through the pulp and keep it well agitated.

A series of experiments were first tried on some ores from Cobalt, being composed chiefly of niccolite, and some smaltite and calcite.

The writer assayed the ore and found it to contain 27.9% nickel and cobalt, the Potassium Cyanide Method being used. It was also found to contain 1.21% iron, and was free from silica.

After about ten hours' treatment by the ammonia process, the nickel-cobalt ore was completely dissolved up, leaving only the small percentage of iron and calcite behind as a residue, or insoluble substance.

The solution so obtained was heated to drive off the ammonia and the arsenic was precipitated; a little ammonia was added to these nickel and cobalt hydroxides, which were filtered off from the arsenic, and was assayed to see what extraction had been obtained. Upon making the assay the extraction was found to be 99%, thus being practically complete.

It might be mentioned here that the nickel arsenides dissolve up first and form a green solution with ammonia; as soon as the nickel is nearly all dissolved up, the solution may be run off and a fresh one added. A pink solution is now obtained which has the balance of the nickel and most of the cobalt in solution. In this way the nickel and cobalt can be partly separated, although there is no sharp line of division. If the air is not passed through for at least 10 hours, only part of the ore will be dissolved up, so that it appears as if this number of hours will be the minimum time.

A smaltite ore from Cobalt was next experimented on, and air blown through for various periods of time.

This ore, according to assay, contained 10% cobalt, and 4% nickel. In treating this in the same way as the high grade nickel ore, it was found to be entirely soluble in ammonia, but not as readily as the nickel. The nickel dissolved out first, giving a green solution; this was run off and more ammonia added; the solution then changed to pink. After 15 hours' treatment the cobalt was practically all dissolved up, leaving no residue or soluble substance behind, as it contained no impurities. On assaying the solution obtained, it was found that a complete extraction had been obtained.

Other Cobalt ores, of various percentages and amounts of gangue, were tried by this method, and the cobalt and nickel was obtained.

In all these experiments the ammonia process seems to work perfectly, and should be more thoroughly investigated as to exact commercial possibilities.

For treating the ore commercially, a large metallic or wooden cylinder with a filtering bottom can be used. The ore, after being finely pulverized and the silver separated, can be introduced and the ammonia solution run in. Air under considerable pressure is then blown up through the mass or pulp, and the ores will go into solution.

The air carries off some ammonia with it, but it is collected easily by passing it through cold water. The water absorbs the ammonia, and when it becomes sufficiently saturated it can be drawn off and run into another tank which is filled with ore and ready for treatment.

When these ores are all dissolved up, the solution of nickel and cobalt hydroxides can be drawn off and the tailings or residue washed, first with ammonia to free any remaining hydroxides, and then with water.

This rich solution of ammonia and cobalt-nickel hydroxides can be heated to recover the ammonia. In doing so, the arsenic in solution is deposited or precipitated and can be filtered off. The filtrate containing the cobalt-nickel hydroxides and a small percentage of arsenic, can be electrolized, and the nickel and cobalt separated from the solution at different times, thus separating them completely.

Or if the oxides are required then if the solution is evaporated to dryness the oxides and hydroxides will be precipitated. Upon heat-

ing the precipitate the hydroxides are converted into oxides, thus giving the nickel and cobalt oxides as a final product.

This process has the following good features:

1. There is very little loss of ammonia, which is almost totally regained, and therefore the loss or expense under this heading would be very small.

2. The process is perfect in this respect, that in nickel-cobalt arsenides and sulphides the extraction is complete.

3. The operations are extremely simple and require very nttle handling.

4. The process is especially suitable where hydraulic and electrical power can be reasonably obtained.

THE DETERMINATION OF AZIMUTH BY OBSERVATIONS OF POLARIS AT ANY HOUR ANGLE.

Louis B. Stewart, O.L.S., D.T.S.

The aim of this paper is to give a concise but detailed account of this useful method of determining the azimuth of a line, or rather, of correcting the azimuth of a line whose direction is approximately known. The observer is assumed to be provided with a surveyor's transit, a sidereal watch, and a nautical almanac, though an ordinary mean time watch may be used.

Stated concisely the method consists in measuring the horizontal angle between the star and some terrestrial point, and noting the time of pointing to the star; the azimuth of the star corresponding to the observed time is then computed, and this, added to or subtracted from the horizontal angle between the star and point, gives the azimuth of the latter. The observation should be repeated after reversing the instrument so as to eliminate the effect of errors of adjustment.

As in latitude 45° N. the azimuth of Polaris takes about $2m\ 09s$ to change by 1′ at the time of culmination, when its motion in azimuth is fastest, it is clear that an accurate knowledge of the time is not necessary. The watch correction may be found by turning the instrument into the meridian immediately before or after the azimuth observations, and observing the time of transit of some equatorial star; this observed time, subtracted from the star's right ascension, gives the desired correction. As an error of 10′ in the assumed direction of the meridian results in an error of only $7s$ in the watch correction in the case of an equatorial star, evidently the direction of the meridian need be only approximately known.

To be more precise the observation is as follows:

Point the telescope to the reference mark, with circle right (or left), and note *H. C. R.*

Then point to Polaris, without transiting, and note time and *H. C. R.*

Then reverse instrument, again point to Polaris, with circle left (or right) and note time and *H. C. R.*

Then finally point again to reference point, without transiting, and note *H. C. R.*

Then turn instrument into the meridian and observe the transit of time star.

The reduction is then as follows:

Find watch correction by the formula $\Delta T' = a - T'$ in which

a = right ascension of time star.

T' = observed watch time of transit.

$\Delta T'$ = watch correction.

(Always subtract algebraically).

Then find hour angle of Polaris at mean of the times of pointing to it by the formula—

$$t = T'' + \Delta T - a$$

in which

t = required hour angle.

T'' = mean of observed times.

a = right ascension of Polaris.

In applying this equation ΔT should be added and a subtracted algebraically. A negative value of t or a value exceeding $12h$ indicates that the star is east of the meridian; in the latter case the resulting value of t should be subtracted from $24h$.

The azimuth of Polaris may now be computed; convenient formulæ for this purpose are:

$$\tan A = \frac{\tan p \sec \phi \sin t}{1 - \tan p \tan \phi \cos t}$$

$$A = \frac{p \sin t}{\cos \phi} (1 + p \sin 1'' \tan \phi \cos t)$$

in which

A = required azimuth.

p = polar distance of Polaris.

= 90° — declination.

ϕ = latitude of place of observation.

The first of these is very convenient where subtraction logarithms are available (see Manual of Dom. Lands Surveys); the latter is an approximate formula obtained from it by expanding the functions of the small angles A and p in series.

The following is an example illustrating the method:

On July 20th, 1904, at a place in latitude 46° 54′ N., the following observations were made to determine the azimuth of a line whose approximate azimuth was 178° 15′ 30″:

Pt. Obs'd.	Circle.	H.C.R.	Watch.
Ref. Pt.	R.	178°15′	
Polaris	R.	0 57 30″	15h 55m 08s
Polaris	L.	181 02 30	16 01 05
Ref. Pt.	L.	358 14	

The meridian transit of α Scorpii was also observed at 16h 23m 00s.

The apparent places of the stars, taken from the nautical almanac, were:

R. A. of α Scorpii = 16h 23m 34s
" " Polaris = 1 25 03
Decl. of Polaris = 88° 47′ 28″
$\therefore$ p = 1 12 32
= 4352″

To find the hour angle of Polaris:

T' = 16h 23m 00s
α = 16 23 34
ΔT = + 34
T'' = 15 58 06
Θ = 15 58 40
a = 1 25 03
14 33 37
t = 9 26 23
= 141° 35′ 45″

The data for determining A are then

p = 4352″
t = 141° 35′ 45″
ϕ = 46° 54′

To find A:

log p	=	3.638689
" *sin* t	=	9.793235
" *cos*	=	9.834595
		13.431924
" 3956.7	=	3.597329
" p	=	3.638689
" *sin* 1″	=	$\overline{6}$.685575
" *tan* ϕ	=	10.028825
" *cos* t	=	9.894121n
" 69.9	=	1.844539n

3956.7
—69.9
$A = 3886.8 = 1°\ 04'\ 47''$

To find azimuth of line:

H. C. R. on Ref. Pt.	=	178°	14′ 30″
" Polaris	=	1	00 00
		177	14 30
Az. of Polaris	=	1	04 47
Az. of Ref. Pt.	=	178	19 17
Az. by traverse line	=	178	15 30
Error of assumed azimuth	=		3 47

SPIRALING RAILWAY CURVES PREVIOUS TO TRACK LAYING.

P. Gillespie, B.A. Sc.

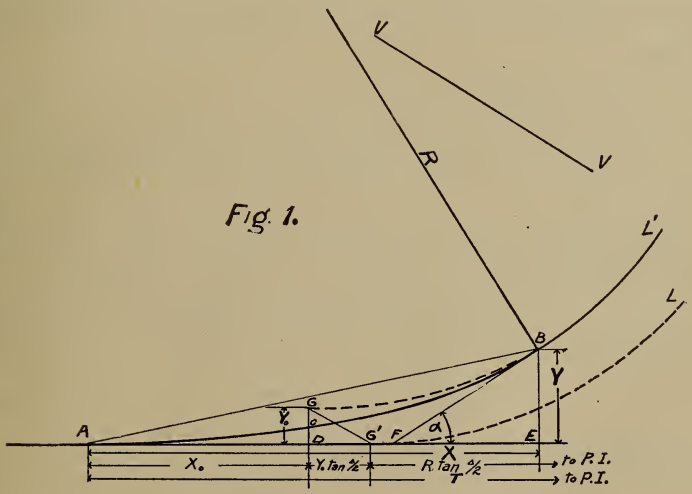
The object of this short article is not to discuss the transition curve in a mathematical way. The essential purpose is to outline a method which, though securing only approximate accuracy, was found to be expeditious, and considering the circumstances under which it was employed answered its purpose very well. The circumstances were these: The centre line had been run prior to construction, but in most cases no preparation for transition curves had been made. In very exceptional instances the centre stakes had been offset toward the centre of curvature by some rule-of-thumb method before the cross-sectioning was done. Frequently the original *B C's* and *E C's* had been referenced and could usually be put back without much trouble. The usual concomitants of hurried work—errors in chainage and faulty alignment on both curves and tangents—were regularly found. Further, the process of centre-staking had to be hurriedly done and hence a ready method was a *sine qua non*. From the fact that almost always the embankments and cuttings had been made from the original centre line, a transition curve that would not throw the stakes too far off centre was an absolute necessity.

Before continuing the subject proper, a little space will be given to stating some facts concerning the Holbrook spiral which was the transition curve employed. The notation which is familiar to S. P. S. students will be retained. The Holbrook spiral is a curve of constantly decreasing radius, or what is the same thing, of constantly increasing curvature. This property is defined by stating that the curvature increases by some constant such as one minute or two minutes for every foot of its length. Where this constant is one minute

per foot, it will be seen that a spiral starting from a tangent will have at the end of 60 feet of its length, a curvature equivalent to that of a one degree curve. At the end of 120 feet its curvature will correspond to that of a two degree curve and at the end of 180 feet it can join on to a three degree curve. Where the constant is 2 minutes per foot, the same properties of curvature are developed in lengths exactly half of those just given.

The process of spiraling involved a shifting bodily of the old curve in a direction parallel to a line bisecting the angle between the two subtangents. The extent of this translation was limited by the fact that the embankments and cuttings were already made to the old centre line, and that it was necessary to keep the centre stakes reasonably near this line. The following figure will assist the explanation.

Fig. 1.



G' is the old B C.

G' L is the original circular curve.

V V_1 is a line bisecting the angle between the subtangents.

G' G is a distance parallel to V V' through the equivalent of which the old circular curve has been moved.

B L' is the circular curve moved as above.

$A\ C\ B$ is the transition spiral.

$B\ F$ is a tangent common to both transition and circular curves.

Now it can be shown that

$s = X$ approximately, where s is the length of spiral;

$$Y_o = \frac{Y}{4}$$

$$a = \frac{s^2 m}{200}$$ where m is the increase of curvature in minutes per foot and may be 1, 2, etc.;

$$X_o = \frac{X}{2};$$

the angle $A\ B\ F = \frac{2}{3}a$;

$$d = \frac{s^2 m}{600}$$ where d is the deflection angle for any station on the spiral measured at A, and s is the length from A to the station in question.

$$T = (R + Y_o) \tan \frac{\Delta}{2} + X_o$$

$$= R \tan \frac{\Delta}{2} \times Y_o \tan \frac{\Delta}{2} + \frac{s}{2}$$ where R is the radius of the circular curve.

Ordinarily, the quantities required in the use of the spiral are tabulated for ready reference in some such way as the following, which is taken from a little brochure issued by the Engineering department of the Canadian Northern Railway at Winnipeg.

TABLE No. 1. $m = 1$.

Degree of Curve	Length of Spiral	Log (R + Y_o)	X_o	Y_o	X	Y	a
2° 0′	120′	3.45714	60′.00	0′.21	120′.0	0′.84	1° 12′
2° 5′	125′	3.43942	62′.50	0′.24	125′.0	0′.95	1° 18′
.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....
5° 55′	355′	2.98865	177′.31	5′.41	354′.8	21′.64	10° 30′
6° 0′	360′	2.98272	179′.79	5′.64	358′.7	22′.56	10° 48′

TABLE No. 2. $m = 2$.

Degree of Curve	Length of Spiral	Log (R + Y_o)	X_o	Y_o	X	Y	a
2° 0′	60′	3.45712	30′.0	0′.05	60′.00	0′.21	0° 36′
2° 20′	70′	3.39019	35′.0	0′.08	70′ 00	0′.33	0° 49′
.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....
4° 0′	120′	3.15627	60′.0	0′.41	119′. 98	1′.67	2° 24′
4° 20′	130′	3.12158	65′.0	0′.53	129′.97	2′.12	2° 49′
.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....
9° 40′	290′	2.77765	144′.5	5′.89	288′.26	23′.57	14° 01′
10° 0′	300′	2.76357	149′.4	6′.51	297′.94	26′.05	15° 0′

A glance at the two preceding tables will show that in the case where $m = 2$, the change in alignment of the circular curve due to spiraling is much less than it is in the other. Since the length of a spiral when $m = 2$ is half of what it is when $m = 1$, the former is to be preferred where curves follow each other with very short tangents between. For these two reasons, the second type was the one employed in nearly all cases.

A reference to the sketch will show that the point A (beginning of spiral) is at a distance $Y_o \tan \frac{\Delta}{2} + \frac{s}{2}$ from the old $B\ C$. Now the magnitude of $Y_o \tan \frac{\Delta}{2}$ depends on Y_o and the angle of intersection. Let us consider a case where $\Delta = 45°$ and where a circular 4° curve has been laid down. Referring to table 2, given above, we find $Y_o = .41$ from which $Y_o \tan \frac{45°}{2} = .17$. This means that the beginning of the spiral is removed from the old $B\ C$ half its own length plus 17, so that the error made in beginning it half its own length from the $B\ C$ hub is quite small. Further, since the perpendicular offset from tangent of an $E.\ C.$ consequent on having the $B\ C$ too far back on its tangent by a distance D, is $D \times sin\ \Delta$,

it will be seen that the error in alignment at the end of the curve would be 17 × ·70711 = ·119, a quantity slightly in excess of a tenth of a foot. Since such an error was usually within the limit of accuracy attainable, the following empirical rule was adopted: For curves up to 4°, if the product of Δ and the degree of curve does not exceed 180, the beginning of the spiral will be located half its length up the tangent from the old $B\ C$. In all other cases, the value of $Y_0 \tan \frac{\Delta}{2}$ was found, its value added to $\frac{S}{2}$ and the $B\ S$ located by chaining back on the tangent from $B\ C$ a distance equal to their sum.

In staking out the spiral, 30 foot chords were used regardless of the plus of each station. Now since $d = \frac{s^2}{300}$ where $m = 2$, and s is the distance measured from $B\ S$, (beginning of spiral) the deflection angles corresponding to the following lengths are:

For 30 feet, d = 3′
" 60 " d = 12′
" 90 " d = 27′
" 120 " d = 48′
" 150 " d = 1° 15′
" 180 " d = 1° 48′

These values can be memorized in a minute's time and can be employed *on all spirals* of the $m = 2$ type.

To illustrate the use of the tables, an example will be worked.

Given

$B\ C$ = 155 + 13.4

Δ = 15° 12′

Degree of curve = 4.

When completed, we shall have an initial spiral, a circular curve and a final spiral.

Now $s = \frac{4 \times 60}{2} = 120'$ and $\frac{s}{2} = 60'$

$B\ S$ = 155 + 13.4 − 60 = 154 + 53.4 neglecting

$Y_0 \tan \frac{\Delta}{2}$

$E\ S$ (end of spiral) = 154 + 53.4 + 120′ = 155 + 73.4

a (from table No. 2) = 2° 24′

Total change in direction of tangent in initial spiral $\Delta = 2° 24'$.

Total change in direction of tangent in final spiral also = 2° 24'.

Total change in direction in both spirals = 4° 48'. Hence the remaining centre angle for the circular curve = 15° 12' − 4° 48' = 10° 24', and the length of this curve will be 10.4 ÷ 4 = 2.6 chains = 260 feet. This gives the plus of B' S' (beginning of final spiral) as 158 + 33.4. From this it is seen that E' S' (end of final spiral) = 159 + 53.4.

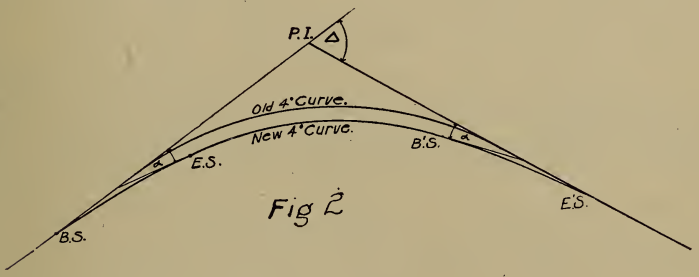


Fig 2

The field notes will be as follows:

Instrument at B S. Ver. at 0° 0'; sight along tangent.

B S sta. 154 + 53.4	0° 0'
First Chord (30')	3'
Second Chord (60')	12'
Third Chord (90')	27'
E S, Fourth Chord (120') = sta. 155 + 73.4	48'

Instrument at E S. Ver. at 0° 0'; sight on B S. Turn off $\frac{2}{3}$ a = 1° 36' when axis of collimation is on the common tangent to both spiral and circular curve.

E S 155 + 73.3	1° 36'
156	2° 8'
157	4° 8'
158	6° 8'
B' S' + 158 + 33.4	6° 48'

Instrument at B' S'. Ver at 0° 0'; sight on E S. Turn off 5° 12' in which case axis of collimation is on the tangent common to both circular curve and final spiral.

Continue turning until vernier reads 5° 12' + $\frac{2}{3}$ of 2° 24 = 6° 48' when the telescope will be sighted on E' S'. By chaining 120' in

this direction, $E\ S$ may be placed. The intermediate stations on the final spiral were sometimes located from this position of the instrument, but more frequently after the transit was moved to $E'\ S'$. The method was as follows :

Instrument at $E'\ S'$.

Ver. at 0° 0′; sight on $B'\ S'$.

$B'\ S'$ 158 + 33.4		0° 0′
First Chord (30′)		21′ (= 48′ − 27′)
Second Chord (60′)		36′ (= 48′ − 12′)
Third Chord (90′)		45′ (= 48′ − 3′)
$E\ S$ Fourth Chord (120′)	= Sta. 159 + 53,4	48′ (= 48′ − 0′)

The instrument will now have accomplished the complete swing of the centre angle Δ, and will be parallel to and nearly coincident with the second subtangent, the difference being a small quantity. The fact that the chainage from $B\ S$ to $E'\ S'$ by the new centre line is less than by the old, was ignored and if $E'\ S'$ for any reason was found to "throw off" from the tangent to a considerable extent, an adjustment involving a distribution of the error was made. $E'\ S'$ was offset by the amount required to place it on its tangent, and each preceding stake similarly by a lesser quantity. This was continued back for as many chains as there were tenths in the offset of $E'\ S'$, the offset of any stake being a tenth less than its neighbor, a chain nearer $E'\ S'$. The effect of this of course was to alter the curvature of the line slightly, this change amounting in the case illustrated to about 4′ per chain The result would be that a 4° curve became a 4° 4′ curve, or a 3° 56′ curve depending on whether the curvature was sharpened or flattened.

Having located the centre line satisfactorily, the "fifties" for the circular portion were put in by offsetting according to the table of middle ordinates. All errors discovered in chainage were allowed to accumulate until the $B\ C$ of the next curve was reached, when the old chainage was adopted. These errors were usually trifling.

Referring again to figure 1, it will be seen that g g′ = $\frac{Y_o}{\sin\left(90° - \frac{\Delta}{2}\right)} = \frac{Y_o}{\cos\frac{\Delta}{2}} = \frac{.41}{.99,122} = .41$ where $\Delta = 15° 12'$

and the curve is four degrees. This means that the maximum offset for this curve, due to spiraling, is .41 of a foot. This maximum would occur of course at half chainage. Ordinary embankments can stand easily such a change in centre alignment, as all small adjustments resulting therefrom can be made in the processes of ballasting and surfacing.

When this change became excessive, correction was made by sharpening slightly the circular curve. This was done by reference to the table of "tangents and externals" for a 1° curve given in all field books. To illustrate, suppose :

$\Delta = 25°$

Curve $= 5°$

and that at half chainage for some reason, the stakes are 2′ off centre of embankment toward the centre of curvature. From the table above referred to

External for 1° curve, Δ being 25°, $= 139'.1$

Hence external for 5° curve, Δ being 25°, $= \frac{139'.1}{5} = 27'.8$

But external is required to be $27.8 - 2.0 = 25.8$

Hence degree of curvature $= \frac{139.1}{25.8} = 5.4 = 5° 24'$

This will be interpreted to mean that a 5° 24′ curve will give centre alignment on the embankment.

It is recognized that there are other problems which occur in the practice of spiraling that have not been touched on here. Transition curves are sometimes required on old lines where the length of track must not be changed, and sometimes also where it is important that the central portion of the circular curve be not disturbed. These are typical cases, but it was thought well to pass them over here since they are more likely to occur on old work than new.

The apology for outlining a method which gives only approximate results is that the correct methods, while involving more labor, were found to give no better satisfaction, this circumstance being due doubtless to the fact that the instrument work and chaining during construction were very much hurried and consequently somewhat inaccurate in minor points.

THE APPLICATION OF DESCRIPTIVE GEOMETRY TO STRUCTURAL STEEL WORK.

C. R. Young, '03.

It is not an uncommon thing, particularly about examination time, to hear doubts expressed by undergraduates as to the practical usefulness of certain subjects of the curriculum. Descriptive geometry comes in for a large share of this criticism, and indeed there are many who regard it as prescribed solely for examination purposes. This, however, is far from the truth. It has long been invaluable to the architect; it is highly important in detailing boilers and machinery; and, since steel has been so widely introduced in structural work, a new sphere of usefulness has been found for it. Nowadays, if one wishes to be thoroughly proficient in structural steel work, he must be well grounded in the principles of descriptive geometry, at least as far as the first year's work in this subject goes at the School of Practical Science.

There are two broad uses of descriptive geometry in practice. The first is to present to the eye an accurate representation of the piece of construction so that the idea will be grasped with a minimum of description. In this sense, it is a picture language. The second use is to solve problems of measurement relating to the piece of construction. These measurements may be distances or angles.

The analytical method might possibly be used for all the problems of measurement which descriptive geometry undertakes to solve, but experience has shown that the latter is superior to the former, if the one who is using it is thoroughly familiar with fundamental principles. The underlying reason for this is, that the method of descriptive

geometry is less abstract than the analytical method. It is easier and more conducive to accuracy to work with lines and angles than to use symbols representing these quantities. The mind grasps the situation much more readily, if aided by the eye, than if left to image the piece of construction and perform the mathematical calculations at the same time. Another justification of the use of the method of descriptive geometry is, that skew connections generally have to be laid out to a large scale anyway, to determine cuts and clearances, and since this layout is involved in the solution by the method of descriptive geometry, it would be better to use this method from the start.

Generally speaking, descriptive geometry as used in practice differs considerably from the descriptive geometry of the technical college. This is due to the desire of the practical man to economize time by omitting everything that is not absolutely necessary in finding the required quantities, and also the tendency to introduce short methods which probably would not always be classed as belonging to descriptive geometry proper. Thus, ground lines are commonly omitted in practice and views thrown off in all directions from an initial view without any special indication of a new plane of projection. Problems 1 and 3 illustrate a method of finding the angle between two planes in space that is quite different from the ordinary method of descriptive geometry.

The chief difficulties encountered in applying descriptive geometry to practical work are a lack of a thorough understanding of fundamental principles and slowness in translating the problem into the language of descriptive geometry. The non-technical man is beset with the first difficulty, and so few are able to use descriptive geometry satisfactorily, that nearly all find it necessary to fall back blindly on the ever-present formula, or hand the job over to a technical man. The latter is handicapped at first in getting the problem re-stated in the old familiar language of descriptive geometry, but this is soon overcome with practice. The result is that the technical man is everywhere ahead, as far as this particular feature of structural steel work is concerned.

In order to illustrate the application of descriptive geometry to this class of work, three typical problems will be solved. No special

merit is attached to any of these solutions, in fact better ones may be in use at the present time. They will probably serve the purpose of this paper, however, that is, to show that descriptive geometry has important applications in structural steel work, and to give some idea of the method of proceeding in problems of this kind. The solutions for problems 1 and 3 have been used in practice, and that for problem 2 is submitted as a possible solution for this case, while not departing too much from the methods of descriptive geometry, which are already well known to the most of you. The descriptive geometry of the first year is all that is employed in these problems, and all who have completed that year should find no difficulty in following the solutions. Proofs of the propriety of certain steps in the solutions involving theorems or problems already demonstrated in the first year are generally not given, for the sake of brevity and clearness. The abbreviations *H.* and *V.* have their usual significance of horizontal plane of projection and vertical plane of projection, respectively.

Problem 1.

Statement.—An 8″ @ 11¼ lbs. horizontal channel with vertical web heads into a 9″ @ 21 lbs. horizontal I-beam, the web of which slopes 2½ in 12 to the vertical. The channel is skewed 6 in 12 to the axis of the I-beam and is turned as shown in Fig. 1 The top of the channel is ½″ below the centre line of the top flange of the I-beam, and its reaction is 3,000 lbs. Detail the connection to the I-beam using ¾″ rivets.

Analysis.—Since the channel, the I-beam and the connection angle must be detailed so as to permit the construction of each independent of either of the others, the solution naturally falls into three parts: (1) the determination of the cuts and punching of the channel; (2) the location of the holes in the web of the I-beam, and (3) the punching and angle of bend of the connection angle. It is evident that the manner of cutting the end of the channel can be determined by a horizontal plan of the whole connection used in conjunction with the vertical elevation of the channel and a section through the I-beam by the plane of the back of the channel. The punching of the channel

and the I-beam, and the size and punching of the connection angle, must be determined by drawing in the two legs of the angle on the webs of the channel and I-beam in their proper places. The angle of bend of the connection angle may be determined by projecting it on a plane perpendicular to the line of intersection of the plane of the back of the channel with the plane of the web of the I-beam. The angle of bend will thus be shown in its true size, and its bevel may be scaled off directly.

Construction.—Draw first $a'\,b'$ a right section of the I-beam inclined $2\frac{1}{2}$ in 12 to the vertical and then project a horizontal plan $a\,g$ down from it. The horizontal projection of the channel $c\,a$ and the cut of its top flange to clear the top flange of the I-beam may be drawn in directly, since the flanges of the channel are parallel to H. To determine how the web and bottom flange are to be cut, a vertical elevation of the channel and the section $a'\,d'$ are drawn in. This latter is a section through the I-beam by the plane of the back of the channel. Any point on this section is on a line passing through its horizontal projection perpendicular to the axis of the channel and its elevation above or below a_1' is found from the right section of the I-beam. A piece of the I-beam past the section is shown for clearness. The elevation of the channel may now be drawn in to clear the I-beam, but its bottom flange should be projected up to its proper position in the right section of the I-beam, to make sure that it does not foul the bottom flange of the beam. In practice, the cuts are more or less dependent on the connection, and must be detailed in conjunction with it. The leg of the angle connecting to the channel is now shown in place, a 5″ leg with two rivets located as shown being used.

The punching of the web of the I-beam is determined in an elevation of the same in the plane of its web, by drawing in $a_2'\,d_1'$ the line of intersection of the plane of the back of the channel with the plane of the web of the I-beam, and plotting in the leg of the angle in its proper position. A $3\frac{1}{2}$″ leg punched as shown will be sufficient.

This leg of the connection angle is then drawn in on the right section of the I-beam and points on it, for example, E, are projected down on the horizontal projection of the connection from the right

section and across from the elevation of the I-beam, thus completing the horizontal projection of the connection. The elevation of the connection is now completed by locating such points as e_2'.

The angle of bend of the connection angle will now be determined as indicated in the analysis. Assume the plane of the back of the channel and the plane perpendicular to $A\ D$ as to the two planes of projection. The projection of the channel on the latter plane will be perpendicular to $a_1\ a_1'$ and the leg of the angle connecting to it may be drawn in at once. To find the projection of the other leg, the following construction is made: From a_2', $a_2'\ f$ is drawn perpendicular to $a_2'd_1'$ and of any length; fg' is drawn perpendicular to $a_2'f$, intersecting the flange of the beam in g'; g' is horizontally projected in g, which is vertically projected in g_1'. On the plane perpendicular to $A\ D$ this point will evidently be projected along the line gg_1' and at a point distant from a_1 an amount equal to $a_2'\ f$. Hence $a_1\ g_1$ is the projection of the centre line of the web of the I-beam and the outstanding leg of the connection angle must be parallel to this line.

Fig. 1 is a complete detail drawing of the connection.

Problem 2.

Statement.—A square pyramidal tower roof is supported by two diagonal hip trusses which carry angle purlins parallel to the eaves, as shown in Fig. 2 (*a*). The tower sides are 13′-5½″, and the rise of the roof at the centre is 4′-6″. The top chords of the trusses are composed of two 2½″ x 2½″ x ¼″ angles ¼″ apart, and the purlins are 2″ x 2″ x ¼″ angles with their backs normal to the plane of the roof and turned as indicated in Fig. 2 (*a*). Detail a bent plate necessary to secure the purlin P to the top chord of the truss $M\ O$, the purlin running over the top of the chord, and as near to the centre line of the truss as possible.

Analysis.—There are four essential things required for a complete detail of this plate: (1) the size and punching of that portion of the plate lying on the truss chord; (2) the angle of bend of the plate; (3) the size and punching of that portion of the plate to which the purlin connects; and (4) the size of the developed plate.

The first step is made by finding the intersection of the plane of the back of the purlin (plane of the purlin) with the plane of the back of the chord (plane of the chord), and after finding the position of this intersection line in a plan of the chord in its own plane, drawing in the plate to scale. The angle of bend of the plate, the second thing required, is merely the angle between the plane of the purlin and the plane of the chord and may be found in any manner. Step (3) must be made by drawing a projection of the connection in the plane of the purlin, and (4) consists in merely straightening the plate out and scaling off the required dimensions.

Construction.—Assume the plane of the eaves as H and the vertical plane which contains O, the apex of the roof, and is parallel to $M\,N$ as V (see Fig. 2 (a)). Let $G\,L$ be the ground line. Draw $a\,b$, $a'\,b'$, the projections of the centre line of the back of the chord, $a'\,b'$ being equal to a half side of the tower and $a\,b$ making an angle of 45° with $G\,L$. The line $b\,b'$ is erected perpendicular to $G\,L$ and made equal to the rise of the roof, or 4′-6″. These distances are laid off to any convenient scale. The projections of the truss chord may now be filled in about the centre lines $a\,b$ and $a'\,b'$.

The first step in the solution proper, that is detailing the portion of the plate lying on the truss chord, is now made. The traces of the plane of the chord are $s\,T\,t'$ and the traces of the plane of the purlin are $s\,S\,t_1'$ $s\,S$ being perpendicular to $G\,L$ and $S\,t'$ making an angle with $G\,L$ equal to the complement of the roof pitch. The intersection line of these two planes is $s\,t$, $S\,t'$, and the plate will be bent along this line. To get the position of this line on the back of the chord, we need a plan of the chord in its own plane, and in order to get this view a vertical elevation must first be drawn. This elevation is drawn parallel to $a\,c$, $a\,c$ being found by erecting $b\,c$ perpendicular to $a\,b$ equal to $b\,b'$ and joining $a\,c$. The portion $D\,E$ of the intersection line $s\,t$, $S\,t'$ is projected in the elevation and plan of the chord as $d_1'\,e_1'$ and $d_1\,e_1$ respectively. The portion of the plate lying in the plane of the chord is now drawn in to scale.

In order to complete the view in the plane of the chord, it will be necessary to show the outstanding leg of the connection plate. This is done by drawing in the connection in the vertical projection and working down to the plan from it. The purlin is shown as clearing

the edge of the chord by $\frac{1}{4}$ inch, and the connection plate, the edges of which are assumed to be perpendicular to the purlin, is made to fit the purlin in this position. The horizontal projection of the connection is found and from it the vertical elevation is thrown down on lines perpendicular to $a\ b$, determining points being located by their elevations above the horizontal line through D. The edges of this leg will be projected perpendicular to the chord in the vertical elevation, since they are perpendicular to any lines in the roof plane which pass through them, and since any lines parallel to the axis of the chord may be considered as contained in the roof plane. The required view in the plane of the chord is secured by projecting down the edges from the vertical elevation and finding their projected length by constructing right-angled triangles as shown for the edge $E\ F$. The distance $g\ h$ is laid off equal to $e_1'\ f_1'$ and the hypothenuse $g\ i$ is made equal to the true length of the edge. The triangle is completed and $e_1 f_1$ is made equal to $h\ i$.

The second step of the solution, which consists in finding the angle of bend of the plate, is performed by the well-known method of Millar, and needs no explanation. The angle of bend is $j\ k\ l$.

The third step is made by throwing out a view in the plane of the purlin from the vertical projection of the connection. The actual length of the bend line $d_2'\ e_2'$ is transferred up from the plan in the plane of the chord. This leg of the connection can now be completely detailed.

The last step is developing the plate. This can be followed from the sketch of the developed plate shown.

Details which have not been mentioned will be found on the drawing.

Problem 3.

Statement.—Two roofs of the same span and of 30 degrees pitch meet at right angles, forming a hip and valley as shown in Fig. 3 (*a*). A 7″ @ 15 lbs. I-beam purlin, the web of which is normal to the plane of the roof, heads into the 12″ @ 31½ lbs. valley beam with vertical web. The valley beam is to be placed at such an elevation that the line of the outside edge of its top flange is in the plane of the top flange of the purlin. The purlin is 3″ below the finished roof.

Detail a connection to the web of the valley beam to carry a reaction of 2,800 lbs.

Analysis.—This problem when analysed is found to be similar to Problem 1, the only essential difference being that only one member is horizontal in this case while both were horizontal in Problem 1. This, with the different style of connection and the different sections, complicates matters to some extent. Precisely the same number of views will be required here as in Problem 1, however, and if that problem has been understood, this one should not prove difficult.

Construction.—In this problem we shall work from the lines of the finished roof, which is the usual method in practice. The horizontal projection of the valley line, which is the intersection of the two roof planes, is $a\,b$, and $a\,a'$ is the horizontal projection of the intersection of the plane of the purlin with the plane of the roof. The horizontal projections of the valley beam and the purlin are then drawn in, that of the purlin being found by first drawing a projection $c\,d$ of the purlin on a plane perpendicular to its axis. The distance which the purlin must be cut back from the intersection point A may thus be found at once in the horizontal projection.

An elevation of the purlin in the plane of its web is then thrown down from the horizontal projection, and the two 5″ x ¼″ connection plates with their rivets shown in as fully as is possible at this stage. Before we can go further with this view we must determine the bend lines of the connection plates, and to do this we must have a vertical elevation of the valley beam.

In order to get the slope of the valley beam the following construction is made: Any horizontal line $e'\,f'$ intersecting the roof line in f' is chosen, f' is projected horizontally on $a\,f$ at f, $a\,g$ is erected perpendicular to $a\,f$, equal to $a'\,e'$ and $f\,g$ is joined. The angle $a\,f\,g$ then represents the slope of the valley beam, and the vertical elevation of that beam must be parallel to $g\,f$ and to $h\,a_2'$, the roof line, which is drawn parallel to $g\,f$. The valley beam must now be placed at such a distance below the roof line that the edge of its top flange will lie in the plane of the top flange of the purlin. The vertical distance between a horizontal plane through A and the centre line of the top flange of the purlin, or also the line $i\,j$ in the top flange of the valley

beam, is $k\ c$, and hence if from the point l on the horizontal line $a_2'\ l$ we lay off a vertical distance $l\ i$ equal to $k\ c$, we secure a point on the vertical elevation of the top flange of the valley beam. This beam is then drawn into scale parallel to the roof line.

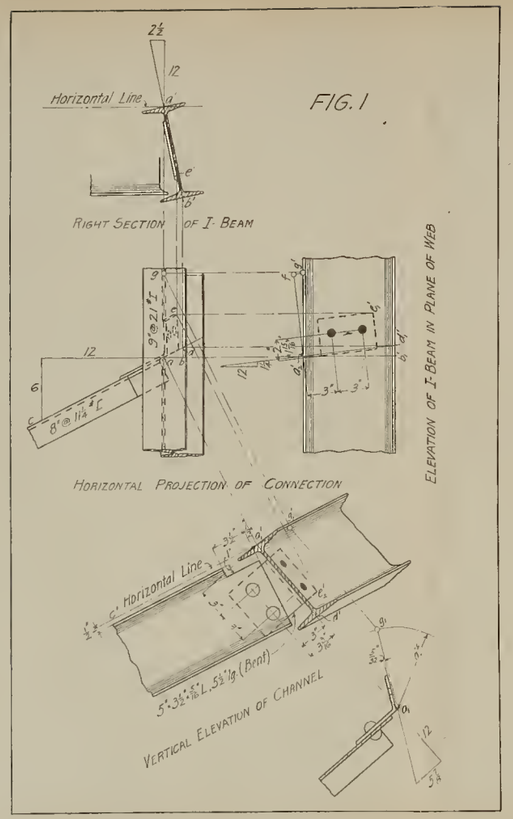
We now proceed to find in this view the position of the line of intersection of the plane of the purlin with the plane of the valley beam. One point on this line is evidently a_2', and another point will be where the centre line of the bottom flange of the purlin pierces the plane of the valley beam. This point will be on the line $m\ n$ and at a distance below the horizontal line through a_2' equal to $o\ d$. The required line will then be $a_2'\ b'$.

The position of this line $A\ B$ in the elevation of the purlin in the plane of its web must now be found. Evidently b will be thrown down on a line perpendicular to the roof line and the point b_1' will be below the roof line a distance equal to $a'\ p$. The section of the valley beam by the plane of the purlin is then filled in about $a_1'\ b_1'$ to see if the connection clears the flanges.

The next step is to find the angle of bend of the connection plates. This is done in the same manner as in Problem 1, by choosing a point h in the plane of the valley beam at a given perpendicular distance $a_2'\ g$ from $a_2'\ b'$ and then finding the line $r\ r'$ along which the point is projected on a plane perpendicular to $A\ B$, the exact location of the point on this line being at a distance from a_2 equal to $a_2'\ g$, a_2 being the projection of the line $A\ B$ on a plane perpendicular to it. The projection of the connection on the plane perpendicular to $A\ B$ is now filled in and the positions of the gauge lines of the field rivets with respect to the intersection line are determined.

The connection to the web of the valley beam is drawn in in its proper position at this stage. It is found that two plates which are straight when developed will be satisfactory for the connection, and that four field rivets located as shown will be amply sufficient for the load.

That portion of the elevation of the purlin which was left incomplete is now filled in, making use of the two last steps in the construction to complete it.



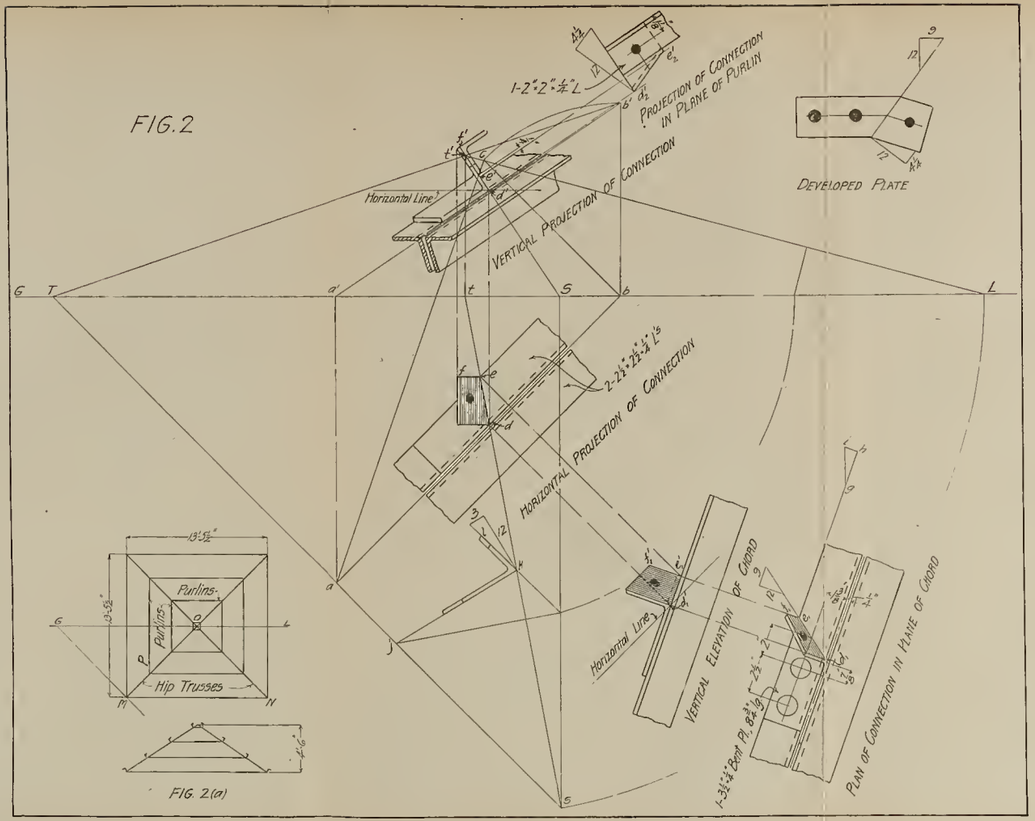


FIG. 2(a)

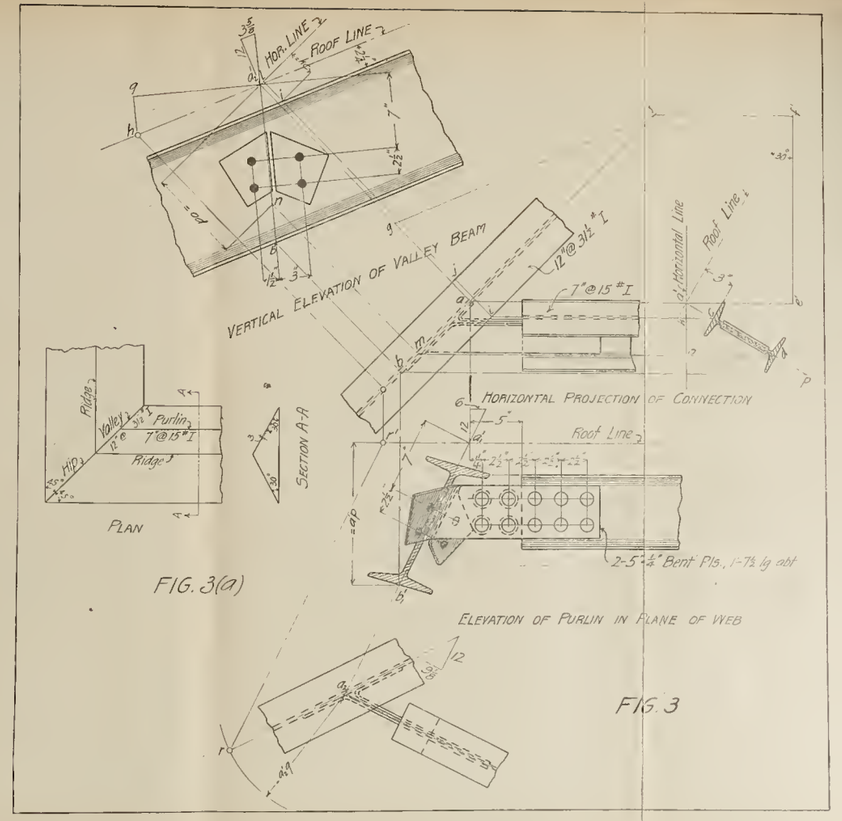


FIG. 3(a)

FIG. 3

THE MANUFACTURE OF ALUMINUM.

J. Horton, '03.

About a century ago a new metal was discovered, which up to that time was all unknown to man, but which was indeed more common than any other metal. Aluminum is now the utilitarian metal of the age; the manufacturing world has become acquainted with its valuable properties and its commercial use has begun.

It is the basic metal of all clays and soils. Rock forming minerals, such as feldspar and mica containing a high percentage of aluminum, are very abundant and widely distributed in nature. It occurs in combination with oxygen, alkalies, iron, silicon and the acids. Its reduction from the oxide by smelting with carbon is impossible at ordinary furnace temperatures. The oxidation of an equivalent of carbon does not furnish nearly the amount of energy required to reduce an equivalent of aluminum. The high heat of formation of its compounds necessitates the absorption of a great amount of heat in its reduction from those compounds.

Many processes, however, for its manufacture have been conceived, some impossible, some impractical and others too costly. Sir Humphrey Davey at the beginning of the 19th century isolated potassium and sodium with his great battery, but could not obtain aluminum. He tried the following experiment: Alumina, the sesqui-oxide of aluminum, $Al_2 O_3$, was melted with potash, $K O H$, and a current passed through. A metallic coating was found on the plates which on analysis was found to be potassium and aluminum; but he could not isolate the aluminum. He melted alumina with potassium in the hope that the following reaction would take place: —

$$Al_2 O_3 + 3 K_2 = Al_2 + 3 K_2 O,$$

but he could obtain no metal. He next heated iron with alumina in an electric arc and obtained an alloy of iron and aluminum.

In 1827 Sir Frederick Wohler reduced aluminum chloride with potassium and obtained aluminum as an impure powder and was able to determine some of its chemical properties. On attempting to melt the powder together in a crucible with a flux of borax the powder disappeared.

It is to H. St. Claire Devielle, a French chemist, that the honor belongs, of having, in 1854, isolated aluminum in a state of almost perfect purity and determining its true properties. He passed vapor of aluminum chloride over metallic sodium and obtained small globules of aluminum which he washed and melted in an earthen crucible and pressed together with a clay rod. Devielle remarks of this process: "Such is the detestable process by means of which were made the ingots of aluminum sent to the Paris Exhibition in 1855. To complete my dissatisfaction at the process, pressed by time and ignorant of the action of copper and aluminum, I employed in all my experiments reaction cylinders and boats of copper, so that the aluminum I took from them contained such quantities of this metal as to form a veritable alloy and had lost almost all its malleability and ductility.

After much labor and experimenting, Devielle found that the reduction by sodium went much better when the double salt aluminum sodium chloride, $Al\ Cl_3$. $3\ Na\ Cl$ was used, and fluorspar or cryolite used as a flux. The whole charge was mixed together and dumped on to the hearth of a reverberatory furnace. On the application of heat the reaction began, the metallic sodium combining with the chlorine of the aluminum chloride, setting free metallic aluminum which flowed together through the agency of the flux cryolite or fluorspar. Works were established at Nanterre, which employed this process and aluminum was made 97% pure at a cost of $9 per pound.

A method of decomposing aluminum sodium chloride by the battery was simultaneously discovered by Devielle in France and Bunsen in Germany. This method, however, could not be employed on the large scale at that time as it was too costly. Aluminum now

became a favorite object of research and in this paper only the more important advances can be discussed.

In 1886 a radical change in the manufacture of sodium was made by the invention of H. Y Castner, of New York city. This gentleman conceived the idea of reducing sodium compounds in cast iron pots from a fused bath of caustic soda. The application of this process on a large scale with the use of gas furnaces and other modern improvements lowered the cost of sodium from $1 to 20c. per lb. For four years Mr. Castner worked in a large laboratory fitted up for the special purpose and after many discouragements in trying to produce aluminum by means other than that of sodium, was led finally to consider that the cheapening of this metal was the most promising method for cheapening aluminum and after much patient hard work success was, at last, reached. The Aluminum Company, Limited, was formed in England, with Mr. Castner as managing director, and large works were established at Oldbury. In 1889 they were producing 500 lbs. of aluminum per day, the selling price of which was $4 per lb. In 1891 they were forced to stop the manufacture of aluminum as its selling price was reduced by the owners of the electrolytic processes below $4 per lb. The great advances made in dynamo-electric machinery led to the revival of the old methods of electrolysis discovered by Devielle and Bunsen. The processes were essentially the electrolysis of a bath of a fused aluminum salt such as chloride or fluoride, the improvements on the older experiments being in details of apparatus used, the use of anodes of mixed carbon and alumina and the use of dynamic electricity.

Now we come to the most practical and valuable discovery in the history of the growth of the aluminum industry. Chas. M. Hall of Oberlin, Ohio, conceived the idea of dissolving alumina in a suitable solvent and electrolyzing the alumina out of it, leaving the solvent unchanged. After trying many salts he found that cryolite, the double fluoride of sodium and aluminum, in a fused state, possessed the property of dissolving alumina in large quantities. This he electrolyzed and found the alumina decomposed, forming aluminum and oxygen, leaving the fluoride bath or solvent unchanged.

Mr. Hall succeeded in getting some Pittsburgh capitalists interested in his process and works were established at Pittsburgh. This was the beginning of the Pittsburgh Reduction Co., now operating large aluminum reduction plants at Niagara Falls, Massena, N. Y., and at Shawinigan Falls, Quebec. At the Pittsburgh works the metal is made into marketable forms, while at their ore plant in St. Louis the alumina is prepared for reduction.

Mr. Hall's process, as it is now operated, consists in passing a large current through the fused solution of alumina in the fluoride bath with a very small difference of potential. The alumina breaks up, depositing aluminum in the molten condition at the cathode and liberating oxygen at the anode. Fresh alumina is then added to the bath and the electrolysis goes on without interruption. The reduction pots are made of iron and are lined with solid baked carbon and are placed in series; the pots, with their carbon linings, as well as the reduced metal lying in them, serve to form the negative electrode or cathode. The anodes are made of carbon and dip into the bath, and are lowered from time to time as they burn away at their lower ends where the oxygen is liberated from the alumina.

The oxygen as it is liberated combines with the carbon of the anodes to form carbon monoxide which bubbles up out of the bath and burns in the air, forming carbon dioxide. The solvent remains unchanged, but for a small loss of fluorine that is liberated at intervals when the amount of alumina in the bath becomes deficient. The electrical resistance of the bath at such a time is greatly increased, and as the current is kept nearly constant by the generators the difference of potential at the bath rises, decomposing some of the fluoride which does not break up at the normal voltage. When a fresh supply of alumina is dissolved in the bath the resistance and voltage rapidly fall again to their normal value.

The consumption of carbon anodes is about 1 lb. of carbon to 1 lb. of aluminum produced. In the case of soft, poorly made carbons, which disintegrate in the bath, the consumption is much higher than this.

The bath is kept at a bright red heat, about 900° *C.* Its specific gravity in the fused state is about 2.14, whereas that of aluminum is 2.54 in the molten state.

In 1886 P. L. V. Heroult of Paris, France, patented a process, the idea or principle involved being exactly similar to the Hall process, and when Heroult applied for United States patents in 1886 the two claims interfered and the evidence given in the patent office showed Hall to be the prior inventor, so that the process in America belongs entirely to Hall. Hall kept on improving his process while Heroult abandoned his, apparently not being aware of its possibilities until Hall's success showed the way. Meanwhile Heroult devised another method of producing aluminum alloys by electrolyzing fused alumina without any bath by a powerful electric current, using melted copper beneath the alumina as a cathode.

Pure aluminum, however, has reached so low a price that metal mixers prefer to make their own alloys and the ready made alloys have lost their market, thereby putting the Heroult alloy process and the similar process of Cowles Bros. out of the race.

The prize of a successful process has been sought most zealously, but the field has narrowed down to two processes which have survived the supreme test of successful commercial application, that of Chas. M. Hall and the similar process of Paul Heroult. One would think that almost every experiment in the bounds of possibility had been thought of and tried, but still the search goes on. A number of processes have been patented within the last two years by Hohman Rubel and Berstein, Reuterdahl, Blackmore, Schwahn, Jensen, Gin, and others, but it yet remains to be proven what their commercial possibilities are.

Bauxite, the hydrated sesqui-oxide of aluminum, is used very largely at the present time in the manufacture of pure alumina. It is simply a pure form of clay that occurs in large deposits or beds in France, Austria, Ireland, Alabama, Georgia, and Arkansas. The Arkansas ore is found in tertiary formations in irregular deposits of 5 to 40 feet in thickness. It is said by some geologists to have been

deposited from solution in carbonated waters. Bauxites, as a rule, have approximately the following composition:

Combined water	H_2O	27%
Silica	S_1O_2	5
Iron oxide	Fe_2O_3	4
Titanium oxide	TiO_2	4
Alumina	Al_2O_3	60
		100

Cryolite, the mineral used for both purposes, occurs in Greenland, and is found in large beds or veins in gneiss. It is a white mineral, having specific gravity 2.95, and hardness 2.5 to 3. Its chemical formulæ is $Al\ F_3$. 3 $Na\ F$., but it frequently contains impurities such as iron carbonate and silica.

Corundum occurs in large deposits in Ontario. It is composed of nearly pure crystallized alumina, but it is very difficult to separate it completely from the rock matter with which it occurs. The best mechanical separation yet attained is 95 to 98% alumina, whereas bauxite can be refined to a purity of 99.9% Al_2O_3. It would be both difficult and costly to treat corundum as bauxite is treated because of the refractory character of the mineral.

Kaolin, white china clay, formed from atmospheric decomposition of feldspar, is the hydrated silicate of aluminum containing, when pure, approximately:

Al_2O_3	40%
SiO_2	46%
H_2O	14%
	100%

The purity of kaolin and the almost inexhaustible beds in which it occurs, stamp it as the natural ore of aluminum. All that is necessary is a cheap process of separating the silica, in which case no other mineral could compete with it as the main staple of the aluminum industry. This is a promising field for chemical experiment, for such a process would be of great value.

The method now in use on the large scale for the refining of bauxite depends on the formation of a soluble compound, aluminate of soda $Al_2\ O_3\ .\ 3Na_2\ O$. The bauxite is treated with carbonate of soda under the influence of a sufficiently high temperature. The alumina displaces the carbon dioxide of the soda, forming aluminate of soda, while the iron, silica, and titanic acid remain unattacked. A simple washing with water then permits the separation of the aluminate from the insoluble products. The bauxite is first finely pulverized and then intimately mixed with enough carbonate of soda to combine with the alumina of the bauxite, and the mixture introduced into a reverberatory furnace which will bear heating strongly. The mass is stirred from time to time and is kept heated till all the carbonate has been attacked, which is recognized by a test being taken which does not effervesce with acids. The aluminate is extracted from the mass by digesting with warm water. The washing is made at first with a feeble solution which has served for the complete exhaustion of a previous charge which was last washed with pure water, forming thus this feeble solution. This gives, on first leaching, solutions of aluminate, concentrated enough to be called strong liquor, which are next treated by a current of carbon dioxide to precipitate the hydrated alumina.

$$Al_2\ O_3\ .\ 3Na_2\ O.\ +\ 3H_2\ O\ +\ 3CO_2 = 2\ Al\ (OH)_3 + 3Na_2\ CO_3.$$

The charge is next washed with pure water which completely removes the aluminate; this solution is the weak liquor which is put aside in a special tank and used as the first leaching liquors on the next charge used. The strong liquor is introduced into a vessel having an agitator where a strong current of carbon dioxide may precipitate the alumina. The carbon dioxide is passed through a series of precipitation vessels so that all of the CO_2 may be utilized. In order to do this the gas always enters first into a vessel in which the precipitation is nearest completion, and arrives at last to that in which the solution is freshest. The precipitated alumina is washed and dried in centrifugal drying machines, and the sodium carbonate solution is evaporated to dryness and used over again.

The atomic weight of aluminum being 27, its chemical equivalent, or the weight of it equal in combining power to one part of hydrogen is 9. Therefore a current of quantity sufficient to liberate 1 part of hydrogen would produce 9 of aluminum in the same time. It has been determined that a current of 1 ampere acting for one second liberates .00001035 grammes of hydrogen; therefore it will set free from combination in the same time .00009315 grammes of aluminum. Now, from thermo-chemical data we know that the amount of energy required to set free a certain weight of aluminum will vary with the compound from which it is produced, but the above equivalent is independent of the compound decomposed; therefore there must be some varying factor connected with the quantity of the current to account for the different amounts of work which the current does in decomposing different compounds of the same element. This is exactly in accordance with the mechanical or thermal equivalent of the electric current, for the statement, "a current of one ampere," carries no idea of the energy represented by that current. We must know against what resistance or with what electro-motive-force that quantity is moved and then we can calculate its mechanical equivalent. Now a current of one ampere flowing against a resistance of one ohm, or in other words with a moving force or intensity of one volt, represents a quantity of energy in one second equal to .00024 calories of heat, or to .1 kilogrammeters of work, and is therefore nearly $\frac{1}{750}$ of a horse power. Hence we can calculate the theoretical intensity or critical voltage of a current necessary to overcome the affinity of any aluminum compound for which we know the thermal data. The heat of combination of 54 kilos. of aluminum with 48 kilos. of oxygen is 391,600 calories; hence

$$\frac{391600}{54} \times \frac{.00000009315}{.00024} = 2.8 \text{ volts.}$$

equals critical voltage for decomposition of $Al_2 O_3$. This data would apply only to the substance named in a fused anhydrous state; when in solution a far greater electro-motive-force is necessary.

The following is a table showing the heat generated by the combination of oxygen with different elements; 16 kilos. of oxygen being used as a basis:

Al with *O*	130,500 calories.
Na "	99,000
K	100,000
Ca	130,000
Mg	145,000
Si	110,000
Zn	85,000
Fe	63,000
Pb	50,000
Cu	40,000
S	35,000
H	68,000
C to *CO*	29,000
C to CO_2	48,000

On looking over the list we see that magnesium is the only element surpassing aluminum. This would indicate the reaction,

$$Al_2 O_3 + 3\ Mg = Al_2 + 3\ MgO.$$

which can be accomplished; but when we consider the case of reduction by ordinary reducing agents, such as hydrogen and carbon, we are confronted in every case with large negative quantities of heat. So large do those quantities appear, that it is very small wonder that attempts to make aluminum in this way have failed. Of course we can now readily understand that by the assistance of some other source of heat, the reaction can be brought about:

$$Al_2 O_3 + 3\ C + \text{electricity (heat)} = Al_2 + 3\ CO.$$

Looked at as a reducing or decomposing agent, the electric current is almighty. A current with an electric-motive-force of 1 volt will decompose any oxide whose heat of combination with one atom weight of oxygen is less than 46,000 calories. We can thus calculate voltages necessary for the decomposition of compounds:

Metal in combination with	Fl	Cl	O	S
K	4.8	4.6	2.2	2.3
Na	4.7	4.3	2.2	1.9
Ca	4.7	3.7	2.8	2.0
Mg	4.6	3.3	3.2	1.7
Al	4.0	2.3	2.8	0.9
Mn	3.1	2.4	2.1	1.0
Fe	2.7	1.8	1.5	0.5
Cu	1.9	1.4	0.9	0.4
H	1.6	1.0	1.5	0.1

In the above we notice that next to the sulphide the chloride is the easiest to decompose, but both these are difficult to produce, and herein lies their chief disadvantage. It can be furthermore observed that if we mix these various salts in one bath and use an electric current carefully regulated as to voltage we can act on one ingredient without disturbing to any extent the others present. We could mix alumina with any fluoride or chloride above aluminum in the list and get only aluminum from the bath. The fact is that, however, alumina is not dissolved by the chlorides but only by the fluorides. These latter are available and are the principal salts used in the aluminum industry. In the Hall process we have present in the bath:

$Al_2\ O_3$ requiring 2.8 volts.
$Al\ F_3$ requiring 4 "
$Na\ F$ requiring 4.7 "

A large proportion of the aluminum manufactured is used as electrical conductors in power transmission, railway feeders, electric light telegraph and telephone wires, and as bus bars. Its use in this respect is due to its low specific gravity, and to its relatively high conductivity. Aluminum conductors only weigh 47% of equivalent copper conductors.

In castings, such as automobile bodies, and in structural work, where lightness and strength is desirable, aluminum is used extensively. Its tensile strength and hardness may be increased very materially by the addition of a few per cent. of copper or nickel or some other hardening metal.

Its use in the steel industry as a deoxidizer is due to its strong chemical affinity for oxygen. A few ounces added to the ton of steel in the ladle, or when it is being poured into the ingot moulds, will produce good sound castings free from blow holes.

As a material for the manufacture of cooking utensils, aluminum has no equal. It seems to be the metal that is adapted more than any other for that particular purpose. The cooking utensils are castings of solid aluminum, or in some cases are spun from sheet aluminum. There is no tin to wear off, no corroding, and no formation of poisonous salts.

Aluminum has an exceedingly bright future in the sphere of usefulness, as well as in the arts, and no doubt will prove of valuable service in the advancement of science and at the same time form a utility in every day life.

School of Practical Science

SIXTEENTH

ANNUAL

DINNER

AT THE

KING EDWARD

MARCH 7, 1905.

A.W.McC. '06

Sixteenth Annual Banquet

OF THE

Ontario School of Practical Science

OF

The Faculty of Applied Science of the University of Toronto

AT THE

KING EDWARD HOTEL

TUESDAY, MARCH 7TH, 1905

Toasts:

THE KING.

CANADA AND THE EMPIRE.

Proposed by Mr. C. R. Young. Replied to by Hon. Dr. Montague.

THE LEGISLATURE.

Proposed by Mr. F. N. Rutherford. Replied to by Mr. T. Gibson.

THE UNIVERSITY OF TORONTO.

Proposed by Mr. E. A. James. Replied to by Prof. A. Baker, Mr. C. H. Mitchell.

THE FACULTY OF APPLIED SCIENCE.

Proposed by Mr. N. H. Sturdy. Replied to by Principal Galbraith, Dr. Ellis.

CANADIAN INDUSTRIES.

Proposed by Mr. K. A. Mackenzie. Replied to by Mr. W. K. George.

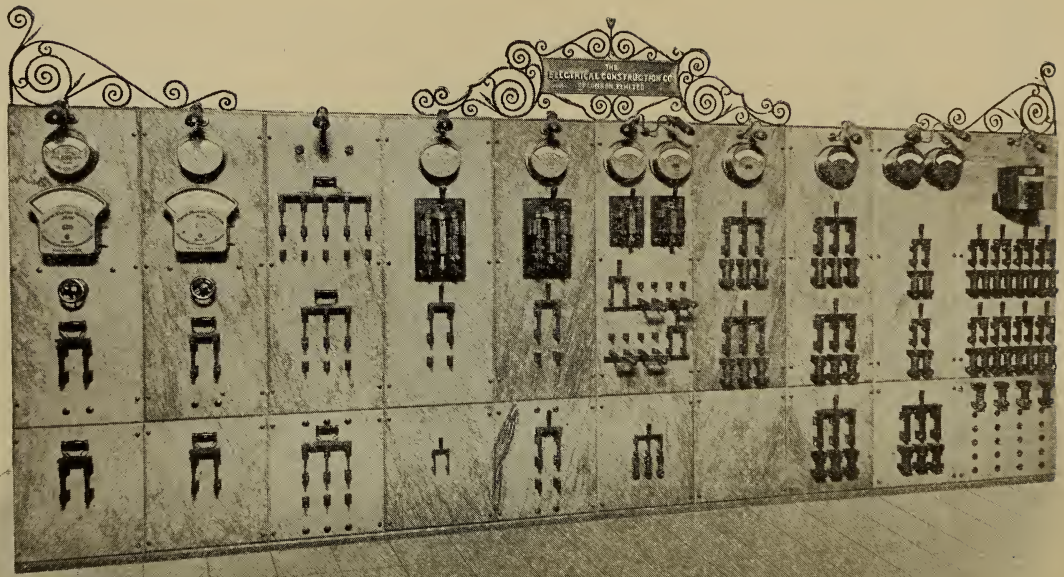
THE ENGINEERING PROFESSION.

Proposed by Mr. W. R. Carson. Replied to by Mr. W. T. Jennings, Mr. E. J. Laschinger, Mr. Somerville.

There were present 315 members of the Engineering Society and their friends. Some twenty graduates were present from Niagara Falls, the guests of Mr. H. D. Symmes, '91.

During the evening it was announced that Hon. Dr. Montague and Mr. W. K. George had each donated a prize of twenty-five dollars to be allotted as the Faculty should see fit.

E. A. JAMES, *Chairman.* C. E. SISSON, *Treasurer.* C. W. GRAHAM, *Secretary.*


THE
ELECTRICAL CONSTRUCTION CO

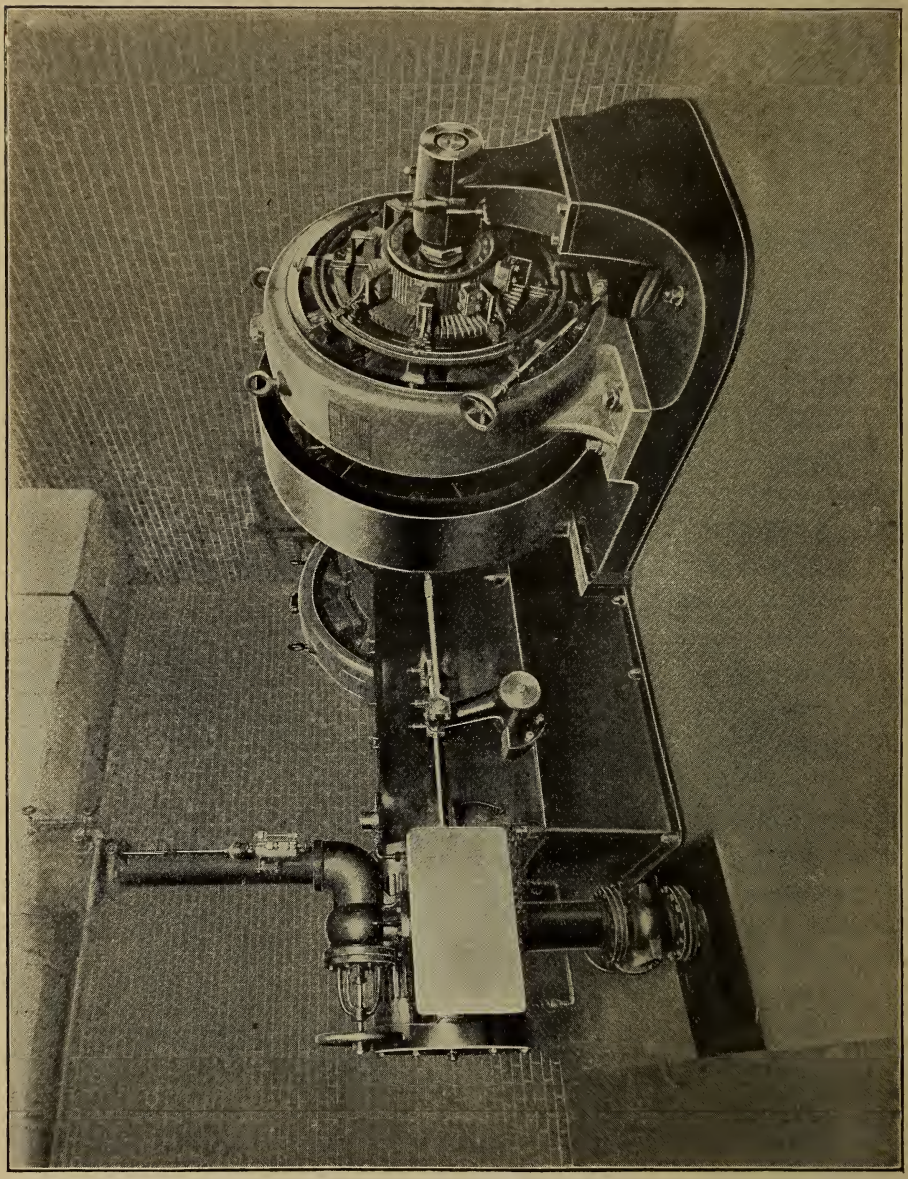
ELECTRIC PLANT IN THE SCHOOL OF SCIENCE CHEMISTRY AND MINING BUILDING.

The cuts herewith show part of the power plant in the new School of Science building. A 200 H.P. Leonard engine is direct-connected to two 75 K.W. 125 volt generators which normally supply a 125-250 volt three-wire light and power service for both the new and old buildings.

The switchboard has some special features. It is arranged so that when large demands are made by the electric furnaces of the electro-chemical department, the generators may be paralleled, in which case about 1,200 amperes at 110 volts can be supplied. The inter-connecting panel at the extreme right of the switchboard serves to make any desired connections between laboratories of both buildings.

A battery of twenty-seven 360 ampere-hour storage cells has been installed for laboratory purposes.

The generators and switchboard were designed and installed by the Electrical Construction Co. of London, Ont.



OBITUARY NOTICES.

JAMES HAROLD BAVIDGE.

James Harold Bavidge, who met his death by drowning at Bronte, Ont., on August 17th, 1904, was a member of the second year in the department of mechanical and electrical engineering.

He was born in Lee, London, England, on March 17th, 1885. His education was begun in Toronto, where he attended Rose Avenue School. Later he matriculated from the county academy in Truro, Nova Scotia. In August, 1903, he returned to Toronto and entered on his course in the School of Practical Science.

In the sad accident which ended his life so suddenly, the School of Science lost a faithful student whose course promised to be one of great credit.

His bright and cheerful ways won him, in his first year, many friends who deeply regretted his untimely death.

WILLIAM C. TENNANT.

Last summer, in an attempt to save his employer's property from damage, Mr. William C. Tennant, B.A.Sc., one of the School's most promising graduates, lost his life. At the time of the accident he was engaged in re-aligning the track between Olden and Sharbot Lake, on the C. P. R., and it was when returning from work on the evening of June 10th, 1904, that a train overtook the hand-car on which he and two of his men were travelling. To save his instrument, Mr. Tennant jumped; the men, in attempting to move the car off the track, lost their footing on a pile of ballast; Mr. Tennant risked giving the car a final push and was killed instantly by the locomotive.

Mr. Tennant was born in Toronto and received his first training in the city's public schools. From Harbord Collegiate Institute he matriculated in 1896, and commenced the study of arts at University College. Civil engineering had now begun to attract his attention, with the result that the year 1897 saw him enrolled at the School of Science. In 1900 he graduated, and the following year pursued post graduate work to round off his college career and more fully equip him for his profession.

It was not until April, 1904, that he entered the employ of the C. P. R., his previous experience being, for the most part, in connection with radial railroad enterprises.

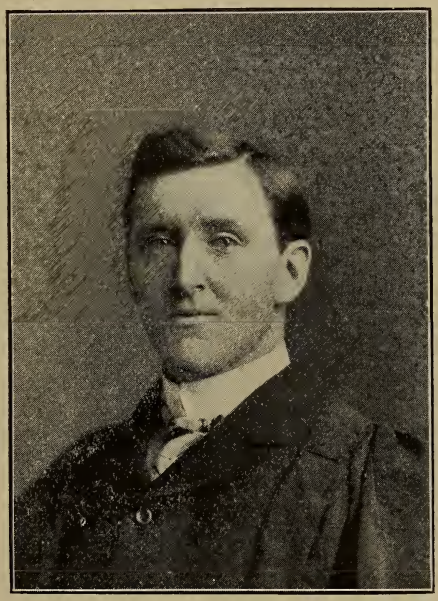
Thoroughness was evidenced in all Mr. Tennant's undertakings; the care and attention to detail which characterized his work aroused admiration in all with whom he came in contact. His generosity towards and his readiness to assist anyone in need, were such that his own convenience invariably made way for the benefit of others; but beyond the circle of his own family and a few personal friends, this self-effacement passed unperceived. A quiet, unassuming nature, and an apparent unresponsiveness prevented his becoming, in the usually accepted sense of the word, a popular man; but if he did make friends slowly, he at least made the friendship fast. May not the vision of such a character have inspired the greatest of dramatists when he wrote:

"The friends thou hast and their adoption tried,
Grapple them to thy soul with hoops of steel."

RUSSEL HENRY BARRETT.

Russel Henry Barrett was born in the Township of Colchester North, in the County of Essex, on the 15th of October, 1876. He attended the public school until fourteen years of age. After spend-

ing a year on the farm he entered Essex High School in 1891, passing the primary examination in 1893, the junior leaving in 1894, and the senior leaving in 1896. After four months' attendance at the Model School at Windsor, he taught school for a year and a-half in the Township of Malden, Essex County.



In October, 1898, he entered the School of Practical Science, Toronto, as a student in civil engineering. He graduated in 1901, and took a post-graduate course the following year, obtaining the degree of B.A.Sc. After leaving the School of Practical Science he was employed with Mr. J. T. Morris, D.L.S., until October, 1904, when he entered the employ of the Georgian Bay Ship Canal Survey.

All through his life Mr. Barrett enjoyed great popularity among his associates. At Essex High School he was President both of the Athletic Association and the Literary Society. At the School of

Practical Science he was President of the Association Football Club during the season 1900-1901, and during the season 1901-1902 he was President of the Engineering Society of the School.

His many attractive qualities and his genuine and trustworthy character won for him many friends, all of whom were greatly shocked by the sad news of his sudden death on February 12th, 1905.

HARVEY STEPHENS.

The death of Harvey Stephens of Collingwood, by drowning in the Georgian Bay on the 11th of June, 1904, was heard with universal regret. He matriculated from the Collingwood Collegiate in the spring of 1903, and entered the S. P. S. in the fall.

Harvey, accompanied by three friends, Gerald Mussen, Harry Andrews and Bud Carrol, set sail in a dinghy from Collingwood, to go to his summer cottage at the mouth of the Nottawasaga River.

The calmness of the day must have made the boys careless. A fisherman, sailing home, passed them, and conversed with them for a while. The boys were never seen alive again.

Next day their boat was found filled with water. Search parties were sent out, but no traces of the boys could be found, and after trying to recover their bodies for nearly a week they were at last successful.

What suffering the poor boys went through no one can tell. The water was icy cold, and although the boys were all good swimmers, no human being could live long in that benumbing embrace.

Although Harvey was only in his first year, his bright and pleasant ways made him many friends.

TREASURER'S REPORT.

MR. PRESIDENT:—

I beg to submit the following statement of balances, receipts and expenditures for the term ending March 31st, 1905:

To balance on hand April 7th, 1904	$	353 69
" amount of members' fees		299 25
" " life members' fees		11 00
" " library proceeds		1,361 95
" " Government grant		75 00
" " from advertising in pamphlet No. 16		34 00
" " advertising and sale of pamphlet No. 17		217 75
Total	$	2,352 64

By amount of publishing pamphlet No. 17	$	326 89
" " printing account		66 28
" " for paper and supplies		1,290 76
" " pins		175 25
" " postage and stationery		36 72
" " election expenses		24 80
" commissions and discounts		13 40
" customs and freight		18 22
" expenses of reps. to McGill and Queen's		40 00
" Editor's salary		50 00
" Assistant Librarian's salary		25 00
" photos, etc		13 00
	$	2,080 32
By balance in Bank of Commerce		272 32
	$	2,352 64

The past year has been a very prosperous one, financially, the stock on hand bringing the balance on hand to about $982.32. However, it will be noticed that very few of the graduates pay the necessary fee which entitles them to life membership and a copy of the annual transactions of the Society.

All of which is respectfully submitted.

G. R. MUNRO,
Treasurer.

AUDITORS' REPORT.

We, the undersigned, have this day examined the books of the Treasurer G. R. Munro, and have found them correct. We find a cash balance on hand of $272.32, outstanding accounts due the Society, $85.00, and the receipts from advertising in pamphlet No. 18. Cash in hands of Librarian, $98.28, and stock on hand valued at $710.00. The liabilities of the Society are the expenses of publication of pamphlet No. 18.

W. BARBER,
A. T. LAING, B.A.Sc., } *Auditors.*

March 31st, 1905.

EXCHANGES.

Ontario Land Surveyors, Toronto, Report, 200 copies.
Michigan Engineering Society, Climax, Mich., Michigan Engineer, 135 copies.
Engineering Society, University of Illinois, Champaign, Ill., Technograph, 125 copies.
Association of Civil Engineers, Cornell University, Ithaca, N.Y., Transactions, 125 copies.
Engineering Society, University of Michigan, Ann Arbor, Michigan Technic, 125 copies.
Perdue Society of Civil Engineers, Lafayette, Ind., 100 copies.
Colorado School of Mines, Golden, Col., 100 copies.
University of Colorado, Boulder, Col., Journal of Engineering, 50 copies.
Ontario Association of Architects, Toronto, Ont., 40 copies.
University of Toronto Studies, Toronto, Ont.
Ontario Historical Society, Education Dept., Toronto, Ont.
Bureau of Mines, Toronto, Ont.
Geological Survey of Canada, Ottawa, Ont.
Queen's University, Kingston, Ont.
Canadian Society of Civil Engineers, Montreal, P.Q.
Canadian Mining Institute, Nova Scotia, Can.
Association of Engineering Societies, Philadelphia, Pa.
Pratt Institute, Brooklyn, N.Y.
Rensallaer Society of Engineers, Troy, N.Y.
Columbia University, New York, N.Y.
Indiana Engineering Society, Indianapolis, Ind.
American Society of Civil Engineers, New York, N.Y.
United States Coast and Geodetic Survey, Washington, D.C.
United States Tests of Metals, etc., Washington, D.C.
Patent Office, London, Eng.
Institution of Mechanical Engineers, London, Eng.
Royal Institution of British Architects, London, Eng.
Society of Chemical Industry, London, Eng.
Institution of Junior Engineers, London, Eng.
Institution of Engineers and Shipbuilders, Glasgow, Scotland.
Societé des Ingenieurs Civils de France, Paris, France.

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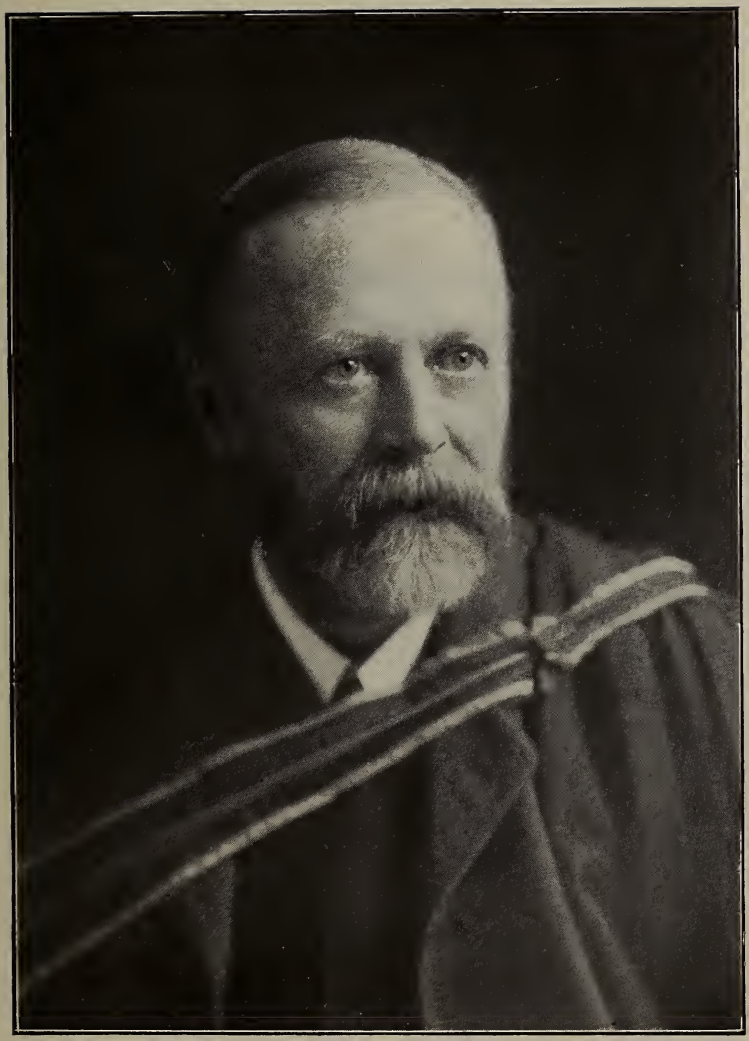

W. H. Ellis

No. 19 1905-1906

TRANSACTIONS

OF THE

ENGINEERING SOCIETY

OF THE

School of Practical Science

FACULTY OF
APPLIED SCIENCE AND ENGINEERING
UNIVERSITY OF TORONTO

Price - - 50 Cents

TORONTO :
THE CARSWELL COMPANY, LIMITED
1906

Entered according to the Act of the Parliament of Canada, in the year one thousand nine hundred and six, by the Engineering Society of the School of Practical Science, in the Office of the Minister of Agriculture.

PREFACE

The nineteenth volume of the Transactions of the Engineering Society of the Ontario School of Practical Science is offered to our readers as a record of part of the work accomplished by the Society during the session 1905-1906.

The papers read before the Society were all instructive and interesting, and as usual the lantern slide was freely made use of in presenting them. A programme of the meetings of the year is printed elsewhere. Some of the papers read have been published in other periodicals and are not reproduced here.

We take pleasure in presenting our readers with a portrait of Dr. W. H. Ellis, Professor of Applied Chemistry, who for many years has been an honorary member of the Engineering Society.

The Society wishes to tender its hearty thanks to all who contributed.

Toronto, April 15, 1906.

J. Gray, 3rd Yr. Rep. | G. Hogarth, 1st Yr. Rep. | W. H. Price, Editor, '05. | R. J. Gibson, 2nd Yr. Rep. | C. Shirriff, Cor. Secretary. | A. Latornell, 4th Yr. Rep.

W. C. Jepson, Librarian. | E. G. Hewson, Assist. Librarian. | E. L. Cousins, Vice-President. | T. R. Loudon, President. | W. Marrs, Treasurer. | F. A. McGivern, Rec.-Secretary.

GENERAL COMMITTEE, 1905-1906.

Elected March 31st, 1905.

President:
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A. W. J. STEWART.

First-Year Representative:
To be elected.

Editor:
P. GILLESPIE.

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Taylor, W. V., O.L.S., A.M. Can. Soc. C.E. '93.
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Jones, T., '06.
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Hall, K., '07.
Hamilton, C. T., '07.
Hara, F. J., '07.
Hare, R. A., '07.
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Hewson, E. G., '07.
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Hogg, T. H., '07.
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Jackson, C. B., '07.
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Melson, J. W., '07.
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Minns, J. B., '07.
Molesworth, G. N., '07.
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Morley, P. F., '07.
Munro, D. G., '07.
Murray, E. W., '07.
Murray, J. D., '07.
Murray, W. P., '07.
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Neelands, R. E. K., '07.
Neilly, B., '07.
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Potter, R. B., '07.
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Procunier, J. F., '07.
Qua, A. H., '07.
Quance, G. E., '07.
Raine, H., '07.
Rannie, J. L., '07.
Richardson, A. B., '07.
Richardson, C. W. B., '07.
Ridler, A. A., '07.
Ritchie, H. C., '07.
Robertson, F. A., '07.
Ronald, C. S., '07.
Rothwell, H. E., '07.
Scholfield, C. A., '07.
Shearer, H. F., '07.
Sheppard, A. C. T., '07.
Siegner, W. A., '07.
Smithrim, E. R., '07.
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Spencer, A. C., '07.
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Stiles, J. A., '07.
Stiver, J. L., '07.
Strathy, E. S. G., '07.
Stuart, J. L. G., '07.
Summers, G. F., '07.
Sutcliffe, H. W., '07.
Taylor, W. C., '07.
Thompson, P. M., '07.
Thomson, O. R., '07.
Toms, C. G., '07.
Tye, H. W., '07.
Walker, W. J., '07.
White, W. R., '07.
Wilkes, E. D., '07.
Wilkie, W. M., '07.
Wilson, A. F., '07.
Wilson, J. M., '07.
Woods, M. H., '07.
Wright, H. G., '07.
Wright, G. W. A., '07.
Young, J., '07.

Adams, O. F., '08.
Agnew, J. N., '08.
Allan, L., '08.
Allison, C. B., '08.
Anderson, R. M., '08.
Annis, S. E., '08.
Arens, R., '08.
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Bain, W. G., '08.
Barber, H. C., '08.
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Birchard, C. C., '08.
Bitzer, A. M., '08.
Black, G. E., '08.
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Bowes, H. F., '08.
Brace, J. H., '08.
Brecken, P. R., '08.
Brown, C. E., '08.
Brown, E. I., '08.
Bryce, W. F. M., '08.
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Buchanan, J. A., '08.
Calvert, D. G., '08.
Cameron, E. P., '08.
Cameron, D., '08.
Campbell, N. A., '08.
Campbell, N. H., '08.
Campbell, J. E., '08.
Carrie, K. N., '08.
Cepeda, M., '08.
Challen, G., '08.
Clark, H. S., '08.
Clarke, F. W., '08.
Clarkson, E. G., '08.
Cleary, F. S., '08
Cockburn, R. B., '08.
Cole, W. E., '08.

Collett, W. C., '08.
Collinson, J. G., '08.
Colvin, C. W., '08.
Corrigan, O. S., '08.
Coyne, J. H., '08.
Cruickshank, A. M., '08.
Cumming, J. D., '08.
Dahl, A. D., '08.
Danks, F. A., '08.
Dann, E. M., '08.
Darroch, J., '08.
Davis, H. C., '08.
Delahaye, W. H., '08.
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Douglas, R. H., '08.
Duff, M. O., '08.
Eagleson, F. M., '08.
Edwards, C., '08.
Ellis, H. C., '08.
Ellis, L. M., '08.
Evans, S. L., '08.
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Iler, S. B., '08.
Jack, R. T. G., '08.
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Jelfs, F. C., '08.
Johnston, J. T., '08.
Kean, D. J., '08.
Keffer, A. H. E., '08.
Kennedy, H. G., '08.
Keys, W. R., '08.
Killip, W. C., '08.
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Lee, F. A., '08.
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Lloyd, N. C. A., '08.
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McKnight, J. H., '08.
McLeod, G., '08.
McMaster, W. A., '08.
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McRoberts, A. A., '08.
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Malone, J. E., '08.
Marlatt, K. D., '08.
Marshall, H. J., '08.
Marshall, R. J., '08.
Michaud, J. A., '08.
Miller, D. J., '08.
Milling, H. F., '08.
Mitchell, A. B., '08.
Molesworth, J. C. P., '08.
Monk, E. D., '08.
Moody, F. H., '08.
Morgan, G. M., '08.
Morice, J. H., '08.
Mowbray, F. E. H., '08.
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Oke, W. V., '08.
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Palmer, E. P. B., '08.
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Peguegnat, M., '08.
Peters, F. M., '08.
Phelps, G. D., '08.
Phillips, F. F., '08.
Pigott, R. B., '08.
Pivnick, M., '08.
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Ransom, J. T., '08.
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Reesor, N. H., '08.
Richardson, F. L., '08.
Ricker, H. A., '08.
Rigg, D., '08.
Robertson, A. R., '08.
Robertson, C. P., '08.
Robinson, R. C., '08.
Rogers, L. J., '08.
Rose, B., '08.
Rose, R. R., '08.
Ross, D., '08.
Rothwell, W. E., '08.
Sanderson, A. U., '08.
Saylor, S. A., '08.
Scott, H. R., '08.

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Shaw, W. E. V., '08.
Spence, J. J., '08.
Squire, G. E., '08.
Stamford, W. L., '08.
Starr, R. H., '08.
Stayner, D. S., '08.
Stewart, A. W. J., '08.
St. Lawrence, J., '08.
Stock, J. J., '08.
Stock, P. H., '08.
Stuart, H. B., '08.
Sutherland, D., '08.
Sword, A. D., '08.
Sylvester, K. B., '08.
Taylor, J. W. R., '08.
Taylor, W. E., '08.
Thomas, V. C., '08.
Thomson, G. G., '08.
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VanNostrand, J., '08.
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Wallace, J. L., '08.
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Weir, R. P., '08.
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Walker, J. A., '08.
Williams, J. A. M., '08.
Wilson, F. D., '08.
Wilson, F. F., '08.
Wing, D. O., '08.
Workman, G. R., '08.
Young, R., '08.
Young, F. L., '08.

W. HODGSON ELLIS, M.A., M.B.

William Hodgson Ellis was born at Bakewell in Derbyshire. His father was the late John Eimeo Ellis, a practising physician, and son of the distinguished missionary to the South Sea Islands and Madagascar, the Rev. William Ellis. The childhood and youth of young Ellis was cast in many varying scenes and countries—at Bradford in Yorkshire, in the Channel Islands, and later, after the emigration of his parents to America, for a short time in Boston, Mass., and then for some years in Illinois. Here it was his good fortune to hear the great American, Abraham Lincoln, speak. The family removed to Canada in the sixties of last century, residing first at Guelph and then at Toronto, where Mr. John Ellis was for some years engaged as editor of the *Canadian Farmer,* the Hon. George Brown's agricultural journal, published as a sort of agricultural companion of the Toronto *Globe.* William Ellis received his secondary education at the Model Grammar School in Toronto, under Principal Checkley, and matriculated at the University of Toronto in 1863, taking high honours in the Natural Science course of those days, and finally winning the gold medal in that department at his graduation in Arts in 1867. Far from devoting himself exclusively, however, to his scientific studies, in which Botany was perhaps his favourite subject, he was equally prominent and successful in literary pursuits, winning the prize for English verse with his poem entitled: "Consider the Lilies," and also the Literary Society's prize for English essay. His admirable talent as a caricaturist, which still contributes to the gaiety of faculty and students on occasion, was much in evidence in his student days, and served to enliven the election campaigns of those days not a little.

When in June, 1866, on the invasion of our beloved country by Fenian hordes, the call to arms was sounded, Ellis, always an enthusiastic and efficient member of the University Rifle Company of the Q. O. R., then a corporal, and afterwards captain of the company, left his examination unfinished and went with his regiment to the front, taking an active part in the engagement at Ridgeway. When the unfortunate retreat of our men began, Ellis, who had been far to the front with his company, fell into the hands of the Fenians, and was taken as a prisoner by them to Fort Erie, and there released on the collapse of the expedition.

After a course in the old Toronto School of Medicine, he graduated as M. B. in 1870, and then spent a year or more in London to finish his medical studies, taking the examination of the Royal College of Surgeons and acting for some time as resident accoucheur in St. Thomas' Hospital.

On his return to Toronto he began practice as a physician, but gave this up on receiving an appointment on the staff of the College of Technology, then located in the Mechanics' Institute building (the present Public Library). On the organization of the School of Practical Science, he was appointed on its staff as Professor of Applied Chemistry—the position which he still holds with such credit to himself and benefit to the School. In addition, he was appointed Public Analyst at Toronto.

Of Dr. Ellis' personal qualities of heart and mind it is unnecessary to speak at length to those who know him. Few professors have won the personal affection of their students to the same extent as he, who may be designated *par excellence* as "the beloved professor." To many he is further known as a constant and never failing friend, while those who have been in the wild places of Ontario with him remember him as a past-master in all manner of woodcraft, and (perhaps rarest of combinations) as an enthusiastic and successful angler, yet absolutely truthful even in his tallest tales.

It is no wonder that, with such qualities and talents, his past students should wish that he may long continue to hold the chair he has for many years filled so efficiently and honourably.

PROGRAMME OF REGULAR MEETINGS, 1905-1906.

October 25, 1905—

Address by Professor Mickle on the "Cobalt Mining Districts."

November 8, 1905—

Address by Geo. Manson, "A New Rotary Engine."

Paper by R. S. Smart, "Patents and their Relation to Engineers."

November 22, 1905—

Address by F. S. Spence on "The City Council and the City Engineer."

December 6, 1905—

Paper by Wm. Snaith on "The Ross Rifle."

January 17, 1906—

Address by Professor L. B. Stewart on "The Labrador Expedition to View the 1905 Solar Eclipse."

January 31, 1906.

Paper by H. E. T. Haultain on "Electrolytic Assaying."

February 14, 1906—

Paper by M. R. Riddell, "Steam Turbines and their Application to Ships."

March 14, 1906—

Address by Dr. Galbraith on "The Pittsburg S. P. S. Old Boys' Dinner, and the Pittsburg Steel Industries."

Paper by L. R. Thomson, "Swing and Lift Bridges."

Messrs. K. A. MacKenzie and Ross Workman were appointed Auditors.

March 28, 1906.

Nominations.

March 30, 1906.

General Elections.

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ENGINEERING SOCIETY

OF

The School of Practical Science

TORONTO.

PRESIDENT'S VALEDICTORY.

GENTLEMEN:—

As retiring President, it gives me the greatest pleasure to thank you for your hearty co-operation throughout my term of office—an office which carries with it the responsibility of upholding the past good record, of meeting present situations, and of anticipating the future development of the Engineering Society of the Faculty of Applied Science of Toronto University.

The business of the Society has, this year, exceeded that of any previous year, as will be evinced by the goodly balance shown in the Treasurer's statement.

In turning over supplies to the incoming executive, instead of showing a statement of the value of stock on hand, the stock itself will be inventoried and handed over. As possible fluctuations in prices may occasion a change in the value of the stock by the beginning of the next academic year, this has been considered a more business-like method of procedure.

The question of a library and reading room is worthy of consideration. At present, owing to lack of rooms, the matter is at a standstill, but when the proposed new engineering buildings—seven in all—are completed, the problem will doubtless be solved.

Should the Engineering Society meetings be made the debating ground for student affairs? This seems to be the real issue of the year. An amendment to the constitution, which made it possible to discuss matters of student interest, was passed at a recent meeting and is now under the consideration of the Council, in pursuance of the University Act. It is my opinion that the real object of the Society, to further engineering interests among its members, should never be forgotten. It must always be advisable to have as the main attraction of a meeting, an address or paper on some point of live interest among engineers.

It has been said before, but will bear repetition, that the affairs of the Society have grown to such magnitude and have become so complex that it is almost impossible for the chief executive officers to do justice to their academic work and at the same time carry on the business of their respective offices. Steps should be taken in the near future to sub-divide the work as much as possible, and thereby lighten the duties of the office-bearers of the Society.

In conclusion, gentlemen, let me recommend for your unstinted approbation the executive committee with whom it has been my lot to work.

Thanking you for the honour which you have done me, and which it has been my earnest endeavour to merit, I remain,

Yours sincerely,

THOS. R. LOUDON.

ELECTROLYTIC ASSAYING—A COMPARISON IN METHODS.

H. E. T. Haultain,

Assoc. Mem. Inst. C. E., Mem. Inst. Min. Met., Mem. Can. Soc. C. E.

Some four years ago I had the pleasure of preparing a paper for this Society, entitled: "The Young Graduate and the Profession of Mining Engineering." Certain parts of this paper were harshly criticized by my friends, and more particularly by my Eastern friends. They said I was lacking in dignity, that I tried to drag in Western freedom of speech, that my wording was unbecoming a professional and scientific man. Dignity, as far as it goes, is a very fine thing. It covers a multitude of deficiencies, but is very often itself a fraud. If any of you have a naturally dignified manner, hang on to it and keep it ready for use, but don't let it get in the way of your work. If you pay much attention to your dignity, you will miss an awful lot of fine work, messy work, undignified work, but work that teaches as nothing else will.

The sentence of mine that seemed to sin most heavily was this: "There are nine and sixty ways of killing a cat." There are nine and sixty ways, and each and everyone of them will be effectual or ineffectual according to its carrying out. If circumstances alter cases, they most assuredly alter methods, and this the Mining Engineer learns very early in his work. It is the ability to adapt methods to circumstances that betokens the man of experience. This ability is founded upon, and is an aftergrowth of, our student training. In the College laboratories we must eliminate the troubles induced by the lack of time and of apparatus of everyday work. We are after the elemental principles, we are pairing off our causes and effects,

hence we need the problem in its simplest form. We want explanations rather than results. It is only when we get out into the field that the circumstances are reversed, and we must have results regardless of explanations.

As an illustration of all this, I am going to put before you the very latest method in assaying. It gives us a very clear case for a comparison of methods. Thirty-eight years ago, the management of the Mannsfeld Copper Works in Germany offered a prize for the best method of determining the copper contents of their ores and smelting products. The prize was won by the electrolytic method of Lucknow. In this method, the copper in a weighed quantity of material is brought into solution, and is deposited by means of the electric current on a plate of platinum. The difference in weight of this plate before and after gives the quantity of copper in the solution. This method is still the most perfect method for copper that we have, and is the recognized standard for accuracy in all important work. It is, however, a very remarkable thing that, although it has been adopted all over the world, and has been in daily use by all types of men for thirty-eight years, practically no change has been made in the form of the apparatus. In both teaching and commercial laboratories it remains the same. The specimen before you is somewhat heavier than that usually found in commercial laboratories, but is otherwise the same. It consists of a cylinder of thin sheet platinum surrounding a wire spiral of the same metal. The cylinder has a total area of one hundred centimetres. It is connected with one pole of the source of electric current, is called the cathode, and receives the deposit of copper. The spiral is connected with the other pole, is called the anode, and the only function it performs is that of carrying the current into the solution. This method of quantitative analysis is not only the most accurate, but it is also the simplest in apparatus required, and in method of procedure. Also it requires less of the manipulator's time and attention than any other method. Furthermore, it is the freest from the personal error or bias. As this last is a very important point, I will explain more fully what I mean by it. In the rival method

of accurate analysis, which is known as the volumetric. the estimate is not made by weighing the product, but is arrived at by determining the quantity of solution that is required to effect a change in the appearance of another solution. The exact point at which this change takes place is a matter of judgment, and not only will differ with different men, but will differ with the same men under varying conditions. Furthermore, if the assayer is checking a known result, he will be unconsciously but powerfully affected in his judgment. With the electrolytic method, on the contrary, he knows nothing about the result until he has made certain calculations after the weighing. Furthermore, all the rival methods, though fairly accurate on comparatively rich samples, fall off rapidly in their accuracy when dealing with low grade samples. The ordinary cyanide method in dealing with mill tailings, for example, is absolutely valueless. Its probable error in the hands of an experienced man may be from twenty to eighty per cent. of the true value of the sample. The Iodometric and the Colorimetric methods, though somewhat more refined, are equally as useless on really low grade samples. I have found it impossible to get really reliable determinations on low grade products in any way other than the electrolytic.

Despite these facts, which will be generally accepted by everybody who has had cause to test them, the electrolytic method, with very few exceptions, is used only on special work. Except in the few cases referred to, even the biggest of our commercial laboratories have not sufficient electrolytic apparatus for more than a few daily samples. This is a truly remarkable state of affairs. But when we consider the lead assay, we find a still more remarkable state of affairs. All our text books on electrolytic analysis tell us that the determination of lead electrolytically is simple and accurate. This fact was known and published a great many years ago, and yet until a comparatively short time ago, I know of no case where it was used in commercial work. Everything that has been said about the advantages of the electrolytic method for copper can be said with still greater force about that method for lead. The methods in general use for lead are cruder, more inaccurate, and less "fool-proof" than the ordinary methods for copper.

And yet there is a very urgent need for expeditious and accurate methods for both lead and copper for everyday work. I know of one river that carries away annually considerably over two million dollars' worth of metals in the shape of mill tailings. Such assays as were made of these tailings were erroneous to the extent of more than a million dollars. I think I may safely say that there are several rivers in America which could tell a somewhat similar tale.

How comes it then that the electrolytic method is not in more general use? A full elaboration of the reasons would be highly interesting, and I think it would be more psychological than technical. By this, I mean that it would have more to do with the man and his mental attitude than with the apparatus or the method. There are three prominent reasons, and one less prominent, which appeal to me. In the first place, the apparatus is expensive. The only metal that can be used for the electrodes is platinum, and the specimens you have before you weigh about thirty-eight grammes for the set, and at the present price of platinum this means about $35. They are sometimes made of thinner metal, and will then cost from $15 to $20 a set. As each set will do only one, or at the most two assays a day, the platinum ware for a commercial laboratory would come very high. There is another reason, and in many cases it is the more important one. It is this: We are all afraid of that of which we are ignorant, and very few chemists know anything about electricity. They have studied it in a general, casual way, and have a hazy notion of the difference between a volt and an ampere, but they have no working knowledge of it, and hence are afraid of it. The third reason is that the ordinary electrolytic copper assay requires from eight to twelve hours for its completion, and consequently results cannot be obtained the same day that the samples come in. I hardly like to mention the fourth reason, because you will not now realize the full significance of it. However, if you will remember it, you will have plenty of opportunity to recognize it in later years. Some conditions in the field do not warrant accurate assays on low grade products. The ordinary methods, both for lead and copper, give results considerably below the truth, and such results are often favourable to those in charge of works.

In regard to the first three objections, Mr. George A. Guess, M.A., has done some most valuable and original work, which should completely wipe out these objections. As far as I know, he is the first man to use electrolytic methods for lead for everyday commercial work, and the first man to demonstrate the advantages of that method for copper for ordinary samples.

He has shortened the time for the determination of copper from eight or twelve hours to less than three, and he and I together, for I had the good fortune to work with him on this interesting subject, designed a set of apparatus which reduces the cost from $15 or $20 to $1.50 per set. Those of you who want to follow more closely the details of Guess' methods will find a full account of it in his paper entitled: "The Electrolytic Assay of Lead and Copper," read before the American Institute of Mining Engineers, July, 1905.

His method for lead is very much simpler, very much more expeditious, and very much more accurate than any other method for lead, and with the new form of apparatus it is very much cheaper, not only in first cost of plant, but also in operating expenses. His method for copper differs mainly in one point from the usual method, but it is a very remarkable difference. I was making some experiments in the concentration of ores by means of grease, and Mr. Guess found that he got with my concentrates a much better deposit of copper on his cathode than with other concentrates of a similar ore. This started him experimenting, and after following it up he found that by adding to his solution a preparation of this crude vaseline, he could get a perfect copper deposit with very much stronger currents of electricity than in the ordinary way. He found that he could reduce the time required for the determination to less than three hours, and still more remarkable, he found he got accurate results in the presence of large quantities of arsenic. He calls his preparation "dope." Some day when he has time to get around to it, he will give it some seventeen syllabled name, or possibly some German will do it for him. He prepares his "dope" by treating crude vaseline, which is known in trade as No. 4 Hard Oil, with hot nitric acid. You will find full particulars in his article already referred to.

Our apparatus is not only so very much cheaper than the old form, but is also very much more convenient to use. I am very proud of my connection with this design, but after all it is nothing more than the application of a little everyday horse sense. We use one cathode, which is shaped like a cricket bat, formed out of platinum foil one-thousandth of an inch thick, corrugated longitudinally to give it rigidity. We use two anodes, one placed on each side of the cathode. These anodes are formed in the same manner as the cathode, but are much narrower, the handle and the blade being of the same width. These electrodes are supported in a plain slit in an aluminium terminal. The old method of supporting the electrodes was to hold them by a binding screw, and this binding screw was generally of copper, which was seriously affected by the fumes from the solution. Not only did the binding screw affect the weight of the platinum, but it was a troublesome thing to manipulate when you were trying to handle several of them in a hurry. These new electrodes represent the absolute acme of simplicity, and they have these advantages over the old form:—

They are cheap, costing one-tenth of the cheapest of the old form.

They are much more easily and quickly attached to, and detached from, the terminals.

The complete set occupies much less space.

The current density is much more evenly distributed over the surface of the electrode that receives the deposit, and consequently the deposit is of more even thickness, with the result that a given area will carry a greater weight of deposit. This is of prime importance in the lead assay.

The electrode being so much lighter, the deposits from very low grade samples can be more accurately weighed.

Mr. Guess introduced these improvements in the laboratory of the Silver Lake Mines, Silverton, Colorado, in the early part of last year. He is now Chief Chemist of the Cananea Consolidated Copper Co., in Mexico, and has introduced his methods into the laboratories there. He has done many thousands of assays of both lead

and copper by these new methods, and has proved beyond all question their practicability and worth. He has also demonstrated the extreme simplicity of the use of the electric current with modern methods and instruments. He has done away with batteries, and connecting up his units in series, he uses the ordinary lighting circuit. The manipulation is very much simpler than the manipulation of a muffle furnace. He has stepped out of a rut of 38 years' standing, and has shown that the most perfect method of assaying, the only perfect method of assaying, is at the same time the simplest and the cheapest, provided that slight alterations are made in the methods.

Well, gentlemen, possibly you think I am too enthusiastic. I certainly am enthusiastic. I am in a position to judge and am free to be enthusiastic. For years my experimental and investigational work called for accurate assays of low grade products, and I failed to get them for love or money. This work of Guess will have a twofold action. It will not only revolutionize the methods of the commercial laboratory in lead and copper work, but it will slowly but surely have its effect upon the operations of ore-dressing or concentration. The present-day sampling and assaying of the various products of the concentrating mill is a disgrace to the profession, a disgrace that is now gradually being recognized. To have a sure and expeditious method for the determination of low grade products is to strengthen greatly the hand of the investigating milling engineer.

In our younger days we were told that there was one right way of doing anything. For 38 years there has been one right way of making electrolytic analysis. There are nine and sixty ways, and Guess has shown us that one at least of the sixty-eight is very much superior to the old right way.

Craigmont, January, 1906.

THE ROSS RIFLE.

WM. SNAITH, '07.

The Ross rifle was adopted in 1901 by the Dominion Government to replace the Lee-Enfield. In England it has not been officially tested, but it has nevertheless received the approval of the King and the Commander-in-Chief, who were well impressed by its many points of superiority over the present service arm. Before its adoption by our own Government, it was thoroughly tested by a committee of experts. The tests were modelled on those of the U. S. Ordnance Board, with every additional rigour of detail that ingenuity could devise, and the rifle passed every test satisfactorily. It is not the purpose of the present paper to discuss the undoubted merits of the new rifle, nor to deal with it at all from the standpoint of the gunsmith or armourer. The methods of manufacture illustrate principles which may be capable of application to other conditions, and it is with the hope that such may be the case that I submit what follows. Inasmuch, however, as this rifle differs in many essential details from any other, it will be necessary to briefly outline some of these points in order to be intelligible later on.

The essential difference between the Ross rifle and all other service arms is in the method of operating the bolt mechanism. As far as I have been able to ascertain, it is the first successful "straight-pull" rifle, and is certainly the first to be adopted by any Government. The handle on the bolt-sleeve does not require to be raised before the bolt can be pulled back, as in the case of the Lee-Enfield—a straight pull back in the direction of the stock opens the action, and a straight push in the direction of the muzzle closes it. The only point of similarity between the new gun and the one in use at the

present time is their calibre—the Ross rifle being chambered and bored to take the standard .303 ammunition. In external appearance the difference is sufficiently striking. The stock is of one piece and completely encloses the magazine, so that the present awkward position of the wrist "at the slope" will no longer be necessary. The magazine is a part of the gun and is not removable. The cartridges may be in a clip or they may be almost as quickly dropped in by hand and retained in a way much simpler than and fully as effective as at present.

The construction of the bolt mechanism is slightly simpler in the case of Mark I. than in Mark II., and the principle is practically the same in both, so that it will be a simpler matter to describe the former and roughly indicate the difference. The mechanical principle on which the bolt action depends is that of the spiral. It is well understood that if the pitch of a screw be increased sufficiently, a pressure on the nut in the direction of the axis will cause the screw to rotate if the nut is prevented from doing so. The nut in this case is the bolt-sleeve, which is prevented from turning by guide slots in the receiver in which it slides. The screw is the spiral on the bolt. Essentially the bolt is a cylinder, the forward portion of which is enlarged to an approximately rectangular section whose width and depth are nearly equal to the diameter of the bolt, and whose length is more than double. When the bolt-sleeve and bolt are drawn back to their farthest position, this rectangular portion of the bolt is a little more than an inch in front of the end of the bolt-sleeve. It also slides in a slot in the receiver and is thus prevented from rotating, and must retain this distance with reference to the bolt-sleeve until it reaches the barrel. Here the slot in the receiver ends and further forward motion of the bolt-sleeve causes the bolt to turn. The rectangular section is so constructed that, when the bolt-sleeve is at the end of its forward travel, it is almost at right angles to its former position in the receiver slot and is securely locked. In drawing back the bolt-sleeve the bolt turns until its end may enter the receiver slot, when both move as one piece. In the case of Mark II., the spirals on the bolt and in the bolt-sleeve are threaded, and during the longi-

tudinal movement these threads are in mesh and take all the thrust of forcing the cartridge into place and cocking the action. At the end of the forward movement, when the bolt-head strikes the barrel, an ingenious arrangement of camming surfaces throws the threads out of mesh and calls into play the spirals which revolve the bolt-head into the locked position. The above operations are reversed during the backward stroke.

The action of the extractor is a good illustration of the attention paid to detail and the ability of the designer of this rifle to take advantage of the peculiarities of its construction. Part of the bolt-head is cut on a 1-20 pitch spiral and engages a shoulder on the extractor which is cut to match. The rotation of the head of the bolt, therefore, draws back the extractor and the empty shell, at a low rate of speed, but with sufficient power to dislodge the most tightly wedged shell without difficulty. When the bolt stops turning, the shell is drawn the remainder of the distance out of the chamber along with the bolt action. At the proper point the ejector acts to force the empty shell from the receiver. So quick is the action of these parts that it is easily possible to empty the magazine before the first shell has reached the ground.

The evident aim of the inventor has been to create a gun that will satisfy the shooting expert, and, at the same time, be simple enough in operation to stand the handling of the raw recruit. Particularly has he succeeded in doing this in the case of the sights. In the construction of the rear sight a very radical departure from almost all the present types has been made. This sight is equipped with a wind-gauge, and is adjustable for differences of 10 yards of distance by means of a micrometer thimble, and has a positive adjustment for each 100 yards by means of small clamps engaging in corresponding slots. The front sight is protected by a metal hood and is not likely to be disturbed in ordinary handling. Ample protection for the rear sight is afforded by the wooden hand guards.

The Ross rifle factory is the only arms factory in Canada, and, while it is surpassed in point of size by many concerns in the United States, it cannot be excelled in respect to modern machinery and

up-to-date management. Economy of production is the aim of any management, but there are widely different means of attaining this end. "A penny saved is a penny earned" is quite true, but a different statement of the same fact through a different definition of the word "save" might be given as "A penny spent (wisely) is twopence earned." This latter statement would indicate the policy of this company and outline their system. High first cost has not been allowed to hinder the adoption of the most modern machinery or the making of special machines. At the same time, proper conservatism has been shown, and there are no monuments to the experimenter in machine tool design to be found in the establishment. Several years of experimenting and preparation were spent in Hartford, Conn. The special machinery and many of the fixtures were constructed by various tool-making concerns of that city. The main building in Quebec was completed and occupied in the spring of 1903, the first machine being started towards the end of March. But it was almost a year before the first rifle made of manufactured parts was turned out. In the meantime, manufacturing considerations, and improvements suggested in the solution of some of the difficulties encountered, led the management to design an improved model which would, besides being an improvement, be more easily manufactured. Their success is attested by a comparison of the new Mark II. rifle with the first design, Mark I. In no instances are there as many operations on any part of the new as in the same part of the old gun, and in many cases the number has been reduced by half. The added simplicity is evidently an important advantage which is thus gained along with a substantial reduction of expense.

The factory itself occupies a magnificent location overlooking the St. Lawrence, on the land made famous by Wolfe in 1759. It is a three-storey 200 x 45 feet brick building, with two wings each 60 x 45 feet. The boiler house is a separate building, 60 x 50 feet, and contains besides the boiler used for heating the plant, the case-hardening furnaces, hardening ovens, and the blacksmith's forge. An old Martello tower is used as a store, and on top of it a 100,000 gallon water tank has been erected in connection with the automatic

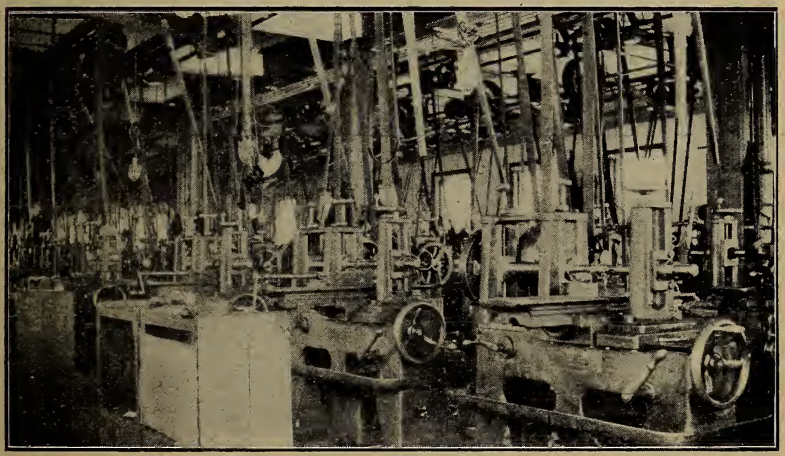
fire sprinkler system. The boiler is used only for heating purposes in connection with a Sturtevant hot air system. The various departments are all run by independent motors of various powers, so that a stoppage of one part of the shop does not interfere with any other.

The main building is entirely devoted to the manufacturing and tool making departments. One of the wings is occupied by the stores, inspection, burring, buffing and finishing departments, while the general offices and draughting room occupy the other wing, of which a small portion and an addition lately built, consisting of a shooting gallery and testing shed, are given up to the Government testing department. In this connection it may not be out of place to mention that the rifles are very thoroughly tested by the Canadian Government before their acceptance. Tested as to workmanship, material and accuracy, by experts, no rifles are allowed to pass unless perfectly satisfactory. These tests, as well as those leading to the adoption of the rifle, are modelled on those of the U. S. Ordnance Board, and the specifications for the steel used in the barrels and other parts state that "in no case must the quality be inferior to the metal furnished to the U. S. Ordnance Board, for use in the corresponding parts of their rifles; these specifications call for identically the same material."

The heavier machinery and the Sturtevant fan are situated on the ground floor along with the Lincoln and B. & S. milling machines, P. & W. profiling machines, barrel drilling machines, rifling machines, lathes and receiver drilling machines. The grinding room occupies one corner. More than half of the second floor is given up to the tool-room (which is very thoroughly equipped) and the tool store. The smaller machines, drills, punch presses, Acme automatic screw machines, plain B. & S. screw machines, hand millers and the special spiral machines, occupy the remainder. The top floor is taken up by the woodworking department and the assembly room.

Two of the most familiar things about most metal-working establishments are conspicuous by their absence—noise and dirt.

The use of electric motors and proper care of the shafting have done away with the one; and constant sweeping and scrubbing of an originally good hardwood floor, the other. In the woodworking department the absence of chips and sawdust is also noticeable. Each cutter is as much as possible enclosed in the mouth of a tube connected to an exhauster which draws in all the chips, etc., and forces them through a large tube down to the boiler house to be burnt. Another feature of the establishment is the use of special trucks and



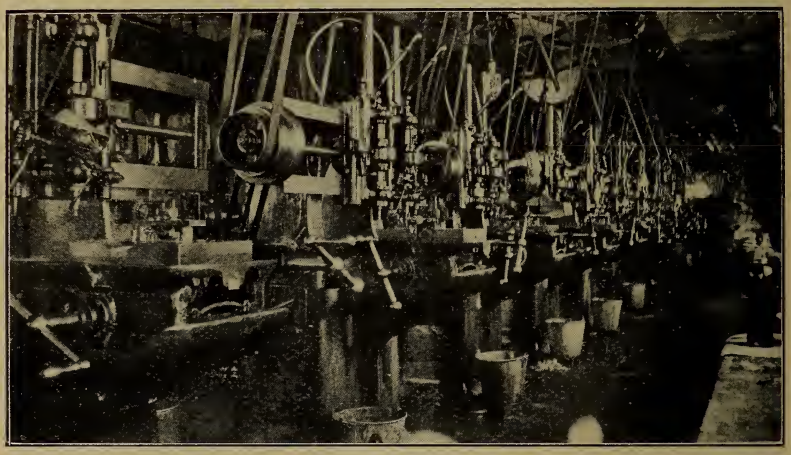
THE LINCOLN MILLERS.

specially designed trays for holding and carrying the wooden stocks and the smaller metal parts.

In the detailed description of the more distinctive types of machines which follows, it is worthy of notice that milling cutters with their many cutting edges are adopted to the exclusion of tools with single cutting edges, wherever possible.

The Lincoln millers are a type of milling machine originated and developed almost entirely in arms factories. They are strong but not very flexible; but are easily adapted to the work for which they are designed. The work is usually held in special vise jaws or

in jigs, and is finished by form cutters or gauges of standard or special cutters. Where the amount of metal to be removed calls for a roughing and finishing cut, it is usual to mount the roughing and finishing cutters on the same arbour and use vise jaws capable of holding two pieces. The piece is transferred from the roughing to the finishing position in the jaw, and a new piece is started in the roughing position. In this way one piece is completely finished at each passage of the milling cutters. The table has an automatic



PROFILERS.

feed in one direction and a horizontal adjustment at right angles to its line of travel, and the spindle has a vertical adjustment of several inches. The use of special fixtures and the automatic feed enable one operator to attend to several machines. Two of these machines have been modified and fitted up to do circular milling, and some of the cuts on the receiver that would seem to call for a lathe are done more quickly and with greater accuracy on these machines.

The Pratt and Whitney profiling machines belong to another class to be found only in arms and sewing machine factories. By means of these, irregular outlines are machined with accuracy and

dispatch. The spindle is vertical and is capable of a certain amount of vertical adjustment. It is mounted in a carriage on a cross-rail which has a horizontal travel at right angles to that of the table. The spindle carriage also carries the former-pin. The distance between the axes of the spindle and the former-pin is constant. The former-pin engages a former-plate on the table in which the outline of the cut is reproduced. The work being securely held in a suitable fixture on the table, the former-pin follows the outline of the plate and the cutter in the spindle, which may be straight or formed, generates the required shape. Adjustment for depth of cut is secured by having the end of the pin and the working edge of the plate at an angle, so that as the pin is forced down the cutter is drawn away from the work and vice versa. The above points are more clearly seen by a reference to the diagram (fig. 6). The machines are generally equipped with two spindles and two pins in the one head. One cutter is then used for roughing and one for finishing. Some of the cuts on the trigger guard are good examples of profiling. The entire outline of the flat portion of this is finished at one setting and the outside of that portion which is visible in the assembled rifle is finished in another setting.

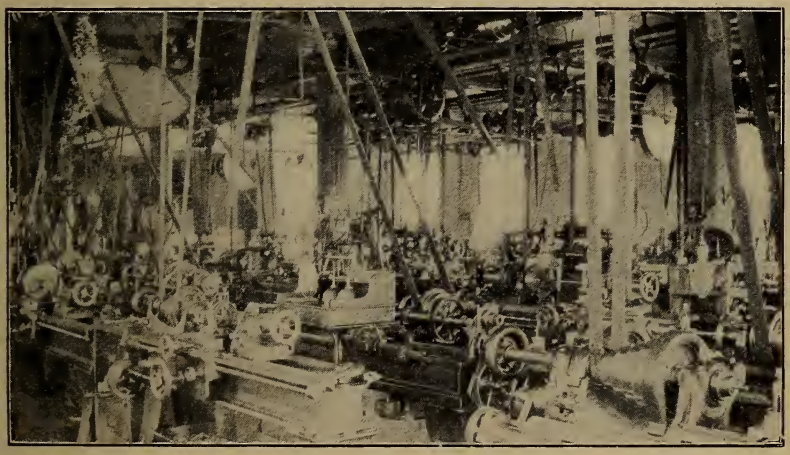
There are 37 Lincoln millers and 26 profilers, the remainder of the milling machine equipment consisting of 12 P. & W. hand millers and 16 B. & S. plain millers. The latter machines are, of course, familiar. The small machines are used on light cuts for which they are designed. The travel of the table in vertical and horizontal directions is controlled by hand levers.

The receivers are drilled in special drilling machines. The drill is stationary and the receiver revolves in a closed chamber in which the oil and chips are prevented from scattering. A "D" drill is used, since the hole must me held within very small limits (.749 to .751), and the single-lipped drill is found to be more accurate than the regular twist drill. It sometimes happens that a drill is not quite correctly made and cuts out a core of wire which is, curiously, slightly longer than the hole it is cut from.

There are also quite a number of small speed drills having from one to six spindles, and a small tapping machine in addition to tapping attachments for some of the drilling machines. Many of the drill jigs are particularly ingenious, those for the receiver and trigger-guard of Mark I. being splendid pieces of designing. The drilling and reaming of all the small holes in these pieces was done in one setting on multi-spindle machines. The jig for the receiver had to occupy seven different positions to accomplish this result. A couple of swaging machines of different sizes also form part of the equipment of the department to which the drills and hand millers belong. The taper ends of the firing pins and the taper shanks of shank mills are finished on these machines.

Several plain screw machines are used; but the practice in this case does not differ materially from that of other establishments. There are two large and one small Acme automatic screw machines, which effect a material saving of time over the methods followed before their adoption. Each machine carries four spindles in one large head, and at least four distinct operations are performed at one time. The manufacture of the micrometer thimble in practically one operation is a good example of the work that can be done. These pieces are made from tubing, turned, knurled, bevelled and graduated on the outside, and bored, threaded and recessed on the inside. The tubing is introduced into one of the spindles, automatically stopped and held. A forming tool then turns the outside and a reamer bores the hole to the correct size and counterbores the front end. As soon as this is done, these tools back out of the way and the head and its four spindles rotate through 90 degrees, bringing a second spindle in line with the tools mentioned, and a second tube starts while the first has come in line with a second set of tools which knurl the outside and stamp the graduation lines on the bevelled surface. At the second quarter turn of the head a third tube starts, the second is moved to the second set of tools, and the first comes in line with a tool which cuts a groove in the middle of the hole. At the third quarter turn a fourth tube starts while the first is being tapped and cut off. Another turn and the first spindle is again in

line with the first set of tools—a new piece is started and the second one is finished. At each subsequent quarter turn of the head a piece is turned out finished completely as far as machine work is concerned. There remains but the stamping of the figures, burring, bluing and inspecting before the piece is ready for the assembly department. The arrangement of the tools above gives an idea of the capacity of the machine. In some cases a drilling attachment takes the place of the first mentioned reamer, but the changes possible may be regarded as practically unlimited. Many of the small screws, etc., are



TOOL ROOM.

finished on a small B. & S. automatic screw machine. To adapt the Acme machines to allow the use of a drilling attachment, it has been necessary to run both drill and work in the same direction, the drill, of course, running the faster. The speed of the work being high in the first place, the difference in the two speeds is not very apparent, and it appears at first that the machine is accomplishing the impossible.

Tool-room equipment and practice in this concern are as up-to-date as in any shop on this continent. From what has been already stated regarding the accuracy obtained in the manufacturing departments, it will be evident that the standard of accuracy in the

tool-room must be very high. If the manufacturing limit, for instance, is .002, it is easy to understand that the tools and fixtures must be extremely accurate in order that the errors in them when inevitably reproduced in the work done, should leave as large a margin as possible. In order that the product of the tool-making department may be accurate, the equipment of the tool-room must not only be up-to-date, but it must be kept in the best condition. In the present instance, roughly speaking, one-sixth of the whole floor space of the plant is taken up by the tool-making department. Its equipment is the best obtainable, and has been added to as has been found necessary. A list of the machine tools may be found interesting: 7 engine lathes of various capacities; 3 toolmakers' lathes; 4 bench lathes; 1 Jones and Lamson flat-turret lathe (1905 model); 1 backing-off lathe for form cutters; 3 shapers; 1 planer; 4 universal milling machines; 1 upright milling machine; 2 hand milling machines; 1 Lincoln milling machine; 2 drill presses; 1 speed drill; 2 screw machines; 1 press for testing purposes in die-making.

The use of unskilled labour in the manufacturing departments renders it necessary that the main consideration after accuracy in a fixture of any kind is that it shall be almost absolutely "fool-proof." It is not sufficient that the design alone should satisfy this condition. The construction must be such as to render impossible any tampering with the position of parts while in use. Thus the cheap and easy method of obtaining a certain important measurement by means of liners of different thickness is not permissible on this class of work. To those who have not attempted work involving the precision that must be obtained in these cases, the time taken to perform the (apparently) simplest operations may seem unreasonable. But there is a vast difference between working to measurements that can be laid off from a scale or rule and to those expressed as decimals. While it may be a matter of a few minutes to locate and drill, say two holes $\frac{3}{4}$ in. apart, it may take as many hours to do exactly the same thing if the distance must be .750 in. In making the drawings for the various tools, etc., the relative importance of different measurements is very simply indicated. Measurements that may be made

with a scale are expressed as fractions, and those that are more important in decimals, the number of places to which they are carried indicating the degree of accuracy.

It would serve no useful purpose to attempt to describe the types of fixtures made nor the methods of making them. At the same time, a few ideas may be obtained in regard to what is here considered good practice. In the case of parts undergoing a number of operations, the first are held within very small limits except on roughing cuts, and they are located from these cuts in subsequent fixtures. As long as the burrs raised by the different cuts do not interfere with anything they are not removed, and gauges and fixtures are designed so as to cause parts to go to the burring and filing department the minimum number of times, and only once if possible. In addition to accurately and quickly locating the work, the fixtures are designed to securely hold it in position by a single clamp. They are easily cleaned of chips and lubricant, and are as often as possible made so that the correct position of the part is the only one it can assume in the jig. No adjustment is left to be made in the fixture itself. Ample provision for all legitimate adjustment exists in the machine and these alone may be used. When a machine is correctly set no change of adjustment can be necessary except that caused by the wear of the cutter. As an example of the accuracy of the majority of the fixtures used, it would be easily possible to replace a piece and remove no more than .0005 in. if necessary. Where much stock must be removed, it is often considered cheaper to design a different fixture for the roughing cut in order to use as large a cutter as possible. Profiling is an expensive operation, and is resorted to when no other way is available. The use of form cutters frequently obviates the use of a profiler, and the tool-room is well equipped for making them. For making the master cutter, a special machine which may be described as a combination of pantagraph and profiler has been designed. The shape of the cut to be made is laid out on a sheet of metal several times enlarged. The former-pin follows this outline as in the profiling machine, and a small milling cutter reproduces the shape in the master cutter. The form cutter itself is turned

to nearly the correct shape in a lathe, gashed in the milling machine, and set up on an arbour in the backing-off machine. The master cutter is mounted in the carriage and finishes the form cutter to the right shape and diameter. Cutters made in this way retain their shape when ground on the cutting face. Practically all the cutters used are made in the tool-room, but taps and dies are invariably bought from reliable firms. High speed steel is used wherever the material worked will stand the heavier cut. In the grinding room both flat and rotary magnetic chucks are used. An attempt to adopt them on some of the profilers was not as satisfactory and has been discontinued. The taper shanks of shank mills of all kinds are finished on the swaging machine; the saving in time and material is very considerable over the usual methods. The dies for some interesting examples of press work have been made in the tool-room, and such of the parts as can be finished in this way are done on the press. The sight leaf is made in several operations and only requires to be drilled and tapped in addition to the press work. The magazine is box-shaped, and is wider at the bottom than at the top. After blanking and bending a punch enters, expands and spreads the bottom to the right shape, and, contracting, is withdrawn. The sear and safety pawl are made on the press and finished by drilling and grinding.

One of the main factors in the success of the modern system of rapid and accurate duplication is the use of accurate gauges. To those who are familiar with the difficulty of making several similar pieces alike in every respect, it will be self-evident that all operations must be gauged by limit gauges, the limit varying with the importance of the operation. The simplest forms of gauges are the plug (fig. 4) and snap (fig. 5) types—the former for circular holes and the latter for circular pieces and parallel surfaces. A limit gauge is a combination of two similar gauges, one of which is as much larger as the other is smaller than the nominal size. One end is marked "Go" and the other "Not go," these terms applying to the gauge with respect to the work. Should both ends "go" or "not go" the piece will be rejected. To enable the operator to distinguish

at a glance the different ends of a gauge, a plug gauge has its "go" end the longer, while the corners of the "go" end of a snap gauge are bevelled off. In addition to these simpler forms, there are many others—practically every important type being represented among the $50,000 worth at present in use among the various departments. A very common kind is known as a "block gauge" (fig. 3). In principle this is a block of metal on which the piece to be gauged is easily held by hand while a finger piece, termed a "rocker," is brought into contact with it and the gauging surface of the block. The opposite sides of this rocker are made so that, with a piece of work of the correct size, it will rest equally on the work and the gauging surface in one position, and when turned over it will rock on one or the other. The front sight hood is shown in fig. 2, and the method of gauging it with a block gauge is illustrated in fig. 3. There are many modifications of this type of gauge, some being very elaborate, having more than one gauging surface and sometimes more than one rocker. In addition to these, there are gauges made on the principle of the micrometer caliper, and very ingenious ones for the measurement of the depths of grooves in circular holes.

The making of these gauges is rightly looked upon as almost the most important branch of the industry. There are numerous problems to be solved in gauge-making, and much ingenuity is called into play. It is comparatively easy to work to a limit of .002 in., and, with a little more experience, to hold work of certain kinds within .0005 in.; but the difficulty is very greatly increased when the limit is reduced to 0. The gauges in which the manufacturing limit is .001 in, or .002 in., would not pass inspection if an error of .0001 in. were discovered. Where the limit is greater, such extreme accuracy is not exacted, but an error of .00025 in. in an essential dimension might easily condemn the gauge, and would never be allowed to pass if it could be corrected.

When it is remembered that all gauges are hardened, ground, and the ones with low limits lapped, the value of one that is at all elaborate can be appreciated. The work of the grinding department in the making of gauges is of great importance, and many points in

regard to the behaviour of hardened steel constantly thrust themselves on the observer. It is a practical impossibility to harden a piece of steel without having it warp to a greater or less extent, and it is equally impossible to grind it without again causing a change of shape in releasing the internal stresses set up in the hardening. Now the grinding allowance is rightly rarely greater than .010 in. The amount of change in a fairly solid piece is almost microscopic, but in long, thin pieces it is frequently very annoying. There are also some features brought out by the grinding machines themselves which, while they can be avoided or overcome by an experienced operator, are worth mentioning. In dry circular grinding, if a piece is long in comparison with its diameter, and is not supported with back rests, the effect of the expansion by heat will be to cause the wheel, after cutting uniformly around the entire circumference, to cut more upon one side than the other. At the next stroke of the table this may be repeated on the opposite side and aggravate the error. The expansion by heat in surface grinding causes the ground surface to become concave. The heat, being more rapidly radiated from the sides than the centre of a flat piece, the centre will expand to a greater extent and more metal will be removed from there, and, after cooling, the surface will be concave. From all this it is not to be inferred, however, that the grinding machines are not accurate. On the contrary, they are the most accurate machine tools built to-day, and their accuracy far surpasses the present requirements of manufacturing. They are the most sensitive indicators of error known. Brown and Sharpe cite several instances. A piece $3\frac{1}{2}$ inches in diameter and 36 inches long was being ground, showing sparks from one side only, but neither a micrometer nor an indicator could measure the error that the machine showed very clearly it was making. Another case was that of a 1 inch diameter plug, carefully ground round and straight and then measured. It was then replaced in the machine and the wheel brought against it until the sparks were just visible around the entire circumference. On remeasuring it was found that .00001 in. had been removed.

In the gauge inspecting department, there is a Pratt & Whitney measuring machine whose capacity is 12 inches, which measures to 1-40 of .001. in. This is the ultimate standard of the establishment and all reference gauges are made to correspond to its decisions.

It not infrequently happens that two surfaces at an angle have to be accurately spaced. Sight measurements are not possible in the case of .0001 and contact measurement is not directly possible, but by an ingenious artifice one is obtained. A surface (usually at right angles to one of the given surfaces) is accurately finished and a surface plate is fastened to it. In the angular groove formed by the surface plate and the angular surface, an accurate plug is laid and the measurement is easily taken over the plug and the flat surface. This method was adopted to secure the measurement given in brackets in fig. 3.

The manufacturing inspection department gauges every piece and every operation before the parts are hardened, and again, in many cases, after the hardening and bluing. Most pieces are manufactured in lots of 100 to 1,000, and when a piece does not gauge, the operator puts a dab of red paint on it and no more work is done on it, although it stays with the lot that it belongs to. The inspection department decides on its value, and, if not irretrievably spoilt, the paint is removed and it goes through again, starting at the next operation after the one from which it was rejected. By this system damaged pieces are easily detected and no more time is spent on them till they are properly inspected.

The stocks are of Italian walnut and are imported in a very rough approximation to their final shape. After a preliminary squaring up cut on a circular saw, they undergo an operation equivalent to centering, for in a system of rapid duplication it is a first requisite that a piece shall be quickly and accurately located and firmly held in a machine with the minimum labour and skill on the part of the operator. A groove is cut lengthwise of the butt and fits a corresponding tongue in the roughing lathes. A circular groove is stamped into the butt, and a long groove is planed in the portion in which the barrel rests in the finished gun. They are rough turned

in two operations, one lathe turning the butt end and the second the smaller portion forward. After this roughing out they are allowed to season for six months or more. They are then re-centered and rough turned in lathes which take cuts over their entire lengths. Three special profiling and bedding-in machines in succession cut out the openings in which the receiver, barrel and trigger-guard rest. The first of these machines carries five profiling heads as well as two bedding-in cutters. It lets in the receiver and part of the barrel and rear sight. The second cuts out the opening for the trigger-guard, and the third cuts out the air spaces under the barrel and finishes the groove for the latter. After the drilling operations, they undergo a final turning in the finishing lathes. The lathes necessarily leave very coarse feed-marks since the feed is coarse, probably $\frac{1}{4}$-in. per turn, and only a cutter having a circular cutting edge can be used on account of the irregular outline of the stock. To minimize hand work as much as possible, the front portion as far back as the rear band, which is comparatively straight, is finished in a special machine which takes out the feed marks and leaves a very smooth surface. The final finishing and polishing are done by hand, and the time taken is surprisingly small. Very little fitting is required as the bedding-in machines work sufficiently accurately to render this unnecessary. The hand guards are the only other parts that are made of wood, and are finished in special machines which do not differ in any essential particular from those previously described.

The barrels for Mark I. were drop forgings of a size leaving slightly over 1-16 in. stock for turning. They were turned in lathes equipped with taper attachments which carried in addition an ingenious follow rest actuated by the taper attachment through a system of levers, so as to follow the taper of the barrel and support it against the action of the cutting tool. The large end was finished in a plain engine lathe. The barrels for Mark II. are turned from bars 1 1-8 inch in diameter. A Jones and Lamson flat turret lathe finishes the large end and the radius cut. The lathes previously mentioned have been re-designed and rebuilt and are used to rough out and finish turn the barrel in two cuts.

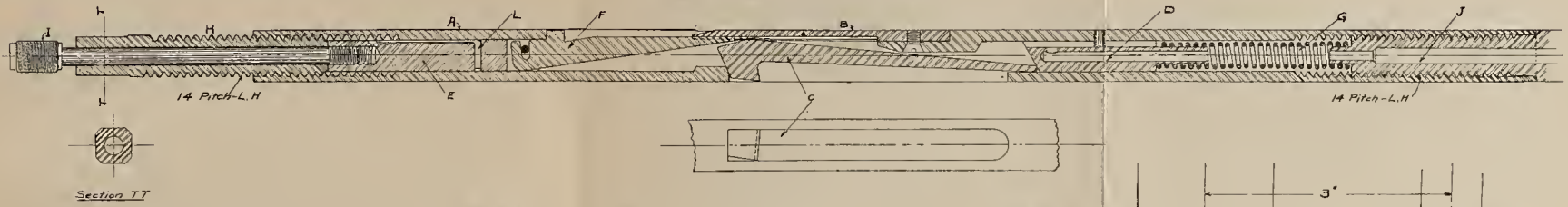
The roughing lathe reduces the 1 1-8 in. bar to from 7-8 in. to 3-4 in., running at a speed of about 100 R.P.M. and feeding 60 turns to the inch. The finishing cut is about 1-32 in. to 1-16 in. deep and is taken after the drilling operation is finished. After the rough turning the barrels are drilled. This is done in special machines in which two barrels are drilled at a time. The small (muzzle) end is held in a chuck and the large end fits freely and turns in a hardened steel bushing. The barrel revolves at a good rate of speed and the drill is forced into it, starting at the large end. The drill itself is the old D style with one cutting edge, and consists of a hardened steel tip about 4 inches long fastened to a piece of steel tubing which has had a substantial groove rolled into one side. A stream of lard oil is forced through the tubing and through a small hole in the tip directly on to the cutting edge, and, returning through the outer groove, carries with it the chips and serves to lubricate the revolving tubing, etc. The diameter of the hole varies within a limit of .001 in. more or less than .296 in., and must be finished by reaming. On account of the primitive method used and the results obtained this operation is rather interesting. The reamer is simply a piece of 1-4 inch square steel welded to a round rod passing easily through the hole in the barrel. The square part is, of course, straight, and the corners are sharp. To make it cut to size, a long thin piece of wood is introduced into the hole along with the reamer and serves to force the cutting edge against the metal. As the wood wears it is blocked out by means of thin strips of tissue paper .001 inch thick. The limits on this hole are nominally .300 in. to .302 in., but in reality the limit is much smaller. The "Go" gauge is 6 inches long and must drop through by its own weight. Since the barrels are never exactly straight after this operation it is easy to see that this limit is not an easy one to hold. After reaming, the barrels are chambered to fit the standard .303 ammunition. The thread for the receiver is milled, and after a rough grinding of the outer surface and a preliminary straightening, they go to the rifling machines. In these machines the barrel is held stationary and the rifling head is drawn through it, revolving so as to give the "twist"

(1 turn in 10 inches) to the rifling. Fig. 1 will serve to explain the mechanism of the rifling head. The head itself, A, is a steel tube, hardened and ground, and threaded at one end to fit a hollow steel tube through which and the passages shown in the head, a stream of lard oil is forced on the cutting edge of the tool. The tool is shown at C, and in this position the head is being pushed through the barrel. At the end of the stroke the piece I strikes a stop, and, being forced against the piece H which screws into the end of the head and thus regulates the travel of I, causes the wedge F to force the cutter, which fits a flat-sided groove in the head, outwards into its cutting position. The friction of the moving parts is sufficient to prevent the tool from forcing the wedge back while a cut is being taken, but, at the end of the cutting stroke, a stop engages the notch in the wedge and forces it back, when the spring G and plunger D force the tool back to its former position. The chip, which is from .0001 in. to .00025 in. thick, and as long as the barrel, is automatically removed by a finger from the front of the tool and the head starts on the return stroke. At the end of the stroke it is indexed, automatically, to cut the next groove. In like manner the third and fourth grooves are cut. When the first groove is reached again, the piece H is automatically turned slightly farther into the head, the travel of I is thus increased, and the tool is fed deeper into the work. The time taken to finish one barrel is about an hour and a quarter, and six machines are required to handle the entire output.

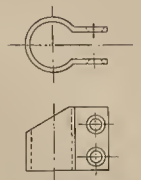
After another straightening the barrels are ground on the outside for the sake of the smooth finish thus obtained and for the accuracy of the fit in the case of the front and rear sights. The grinding is done on large B. & S. plain grinders. Previous to the rifling the barrels are tested for ability to resist explosion with a heavy charge of black powder. A final inspection and straightening takes place before the barrel is coloured. The work of the barrel straightener has already been mentioned. The importance of this part of the work does not require to be emphasized. This operation, on which the accuracy of the rifle depends absolutely, is almost the

Fig. 1

SECTION THROUGH RIFLING HEAD

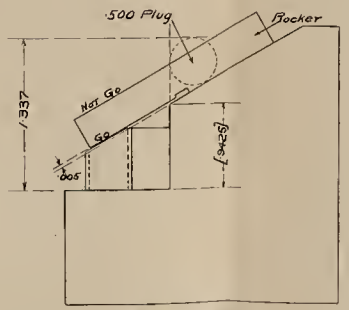


Section TT



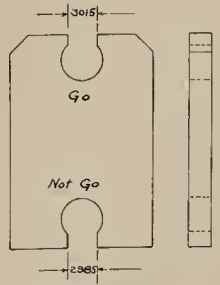
FRONT SIGHT HOOD

Fig. 2



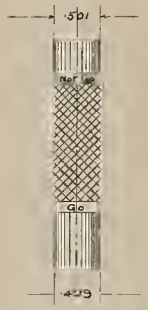
BLOCK GAUGE

Fig 3



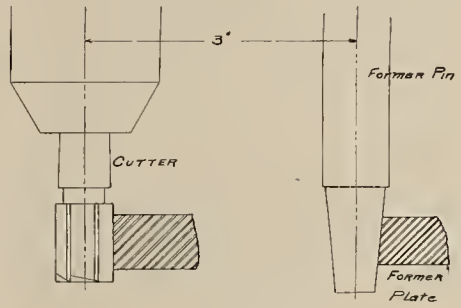
SNAP GAUGE

Fig. 4



PLUG GAUGE

Fig. 5



TABLE

DIAGRAM OF PRATT & WHITNEY PROFILER.

Fig. 6

W.T.S. '05.

only one which is left to be the result of the skill of the workman. Barrel-straightening machines have been devised, but have never yet been successful. By noting the position of the shadow cast in the hole in the barrel by a line on a ground glass window, the straightener knows where to strike the barrel to remove the bend. The actual straightening is done with a light sledge with the barrel resting on two supports.

The bolt and bolt-sleeve are the distinctive parts of the Ross rifle. It is unnecessary to enumerate the majority of the operations on either. The most important operation is the production of the .486 spiral cut in each. This is done on the special spiral machines which have already been mentioned. These machines take a shaving out in both cases. In cutting the internal spiral in the sleeve the action is very similar to that of the rifling head. The backing away of the cutters during the return stroke and the feeding are done automatically, but the indexing is done by hand. Without the aid of extensive drawings it would be impossible to describe these machines.

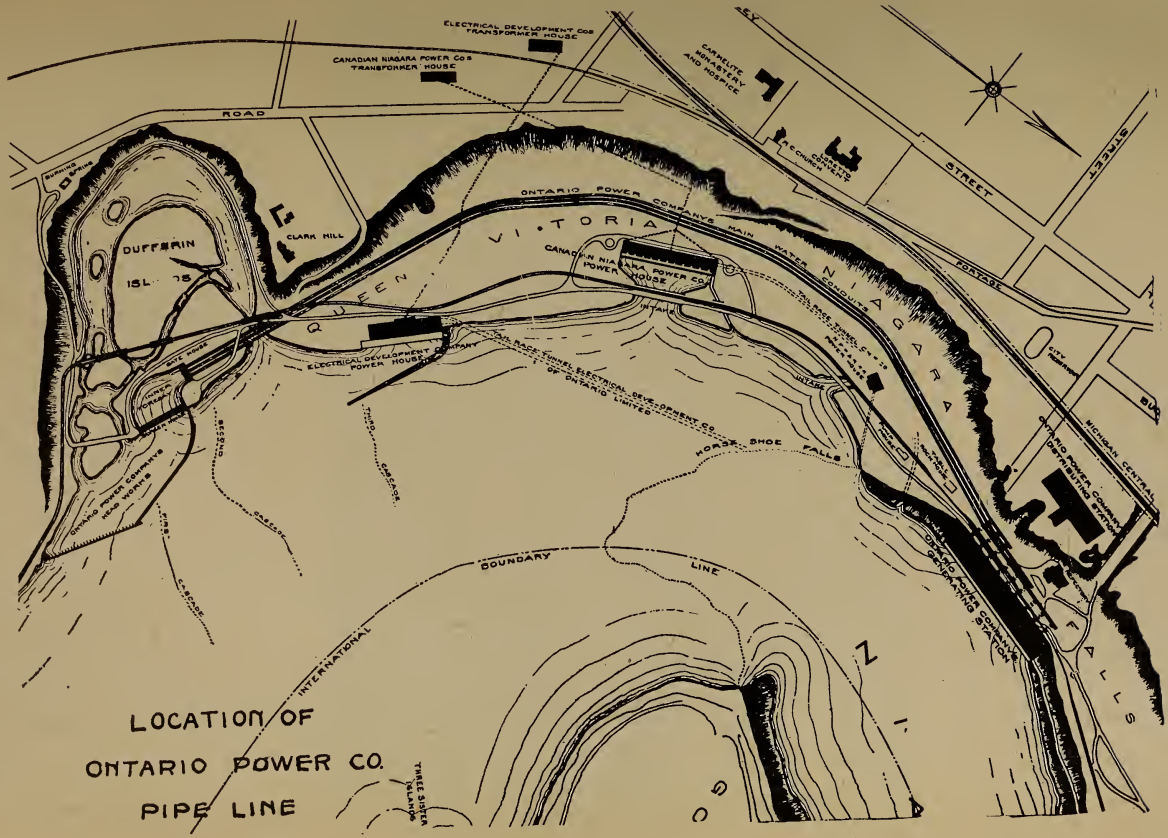
In conclusion, a few figures may give a rough idea of the importance of the industry apart from mechanical considerations. Approximately 400 men are employed in the day and night gangs. The wages bill is close upon $5,000 a week. The plant and stock, exclusive of finished product, has a bank value of about $750,000, and the product, 2,000 rifles a month, at the price for which they are bought by the Canadian Government, $25 each, is worth $50,000. For the opportunity to become familiar with the various manufacturing departments and for many items of interest, I desire to acknowledge my indebtedness to the Manager, H. L. Bock, and the Mechanical Engineer, W. O. Barnes.

Quebec, Sept. 25th, 1905.

CONSTRUCTION OF 18 ft. STEEL CONDUIT OF THE ONTARIO POWER CO., NIAGARA FALLS.

T. H. Hogg, '07.

The Ontario Power Company of Niagara Falls first received permission from the Ontario Government to take from the Welland river sufficient water to develop 200,000 horse-power. They were authorized to convey it by means of an open canal to and through the Queen Victoria Park and to use it in a power-house located below the Falls. Afterwards, this agreement was changed, as the Company's engineers decided that water could be more advantageously taken from the Niagara River, at or near the Dufferin Islands, and could be conveyed to a point below the Falls where the fall could be utilized. The Park Commissioners representing the Government, in consideration of this change, stipulated that the open hydraulic canal through the Park should be abandoned, and that all the water required by the Company should be conveyed under the surface of the Park in conduits or pipes. In consequence the present location was chosen and agreed upon, and it was decided to carry the water by means of three pipes each of 18 ft. diameter. As there never had been an installation comparable with this the question arose as to what material should be employed in the construction of pipes of such size. Steel, concrete and wood were in turn proposed. The feeling was rather against steel at first, and as concrete would be too expensive, the choice fell on wood. Designs were drawn up for a wooden pipe, to be made of California red-wood, of staves 4 by 8 inches, bound together by iron rods acting as hoops. An experimental section was built and tested, and although it stood the test very well, after considering the question of expense and durability, it was decided to use steel and a design was accordingly made.


ELECTRICAL DEVELOPMENT CO'S TRANSFORMER HOUSE
CANADIAN NIAGARA POWER CO'S TRANSFORMER HOUSE
CARMELITE MONASTERY AND HOSPICE
R.C. CHURCH
CONCRETE CHAMBER
ROAD
STREET
FORBES
DUFFERIN ISLAND
CLARK HILL
ONTARIO POWER COMPANY'S MAIN WATER TUNNEL
QUEEN VICTORIA NIAGARA
CANADIAN NIAGARA POWER CO. POWER HOUSE
ELECTRICAL DEVELOPMENT COMPANY POWER HOUSE
TUNNEL OF ONTARIO POWER CO.
TUNNEL OF ELECTRICAL DEVELOPMENT CO OF ONTARIO LIMITED
HORSE SHOE FALLS
ONTARIO POWER COMPANY'S HEAD WORKS
BOUNDARY LINE
INTERNATIONAL
ONTARIO POWER GENERATING STATION
MICHIGAN CENTRAL
THREE SISTER ISLANDS
LOCATION OF ONTARIO POWER CO. PIPE LINE

The pipe consisted of a cylinder 18 ft. in diameter, in sections 8 ft. long. Each section was made up of three plates, the plates being half inch steel. Around this cylindrical section were riveted 7-inch bulb tees or deck beams. These went over the top and down two feet below the centre line on either side. Two were placed on each section to act as stiffeners. The bottom part of the pipe had none of these.

The Jenckes Machine Company of Sherbrooke, Quebec, were awarded the contract of installing the pipe, in spite of the fact that quite a number of American firms submitted tenders. Their method of procedure was to construct a shop and erect a temporary plant centrally located adjacent to the proposed line. From this centre, tracks for the transportation of material and its erection were laid each way parallel to the line. On account of the large size of plates, all assembling had to be done in the field, and for the conveyance and handling of these plates, a steam-actuated derrick moving on the track was employed. For the purpose of riveting, caulking, sand-blasting, reaming, and other operations, a large compressed-air pipe-line was run from the temporary plant each way along the line of the penstock, which main was tapped at various places for the operation of the pneumatic tools used throughout the work. The machines used for the preparation of the material were of the ordinary every-day type, with the exception perhaps of the rolls used for bending the bulb tees. These after a good deal of experiment were made to work satisfactorily in bending the bulb tees cold.

The shop procedure, briefly, was to mark the plates by template as they were received, and punch them under the ordinary power-driven punch. They were then scarfed and sheared for caulking. This operation was done with a Lennox bevel shear, which at one operation trimmed the edge of the plate to the required width and bevelled it to an angle of 45 degrees, for caulking. The bevelled sheet was then passed to the rolls, where at one operation it received the desired curve. From the rolls, the plate was passed outside the shop and there sand-blasted on the edges or lap, and coated with oil to prevent rust while handling. It was then ready to send along to the trench.

A few words might be said here as to the character of the material excavated. Beginning at the Dufferin Islands, where the forebay is situated, the first 1,500 ft. was rock cut; then came about 3,000 ft. of clay or gravel with some 2,900 ft. of rock cut at the end. Good bottom was thus available throughout the entire course. Drain tile were laid 8 ft. on either side of the centre-line and 2 ft. below pipe grade. These ran from 6 in. to 10 in. in size. The 6 in. tile

VIEW OF DERRICK.

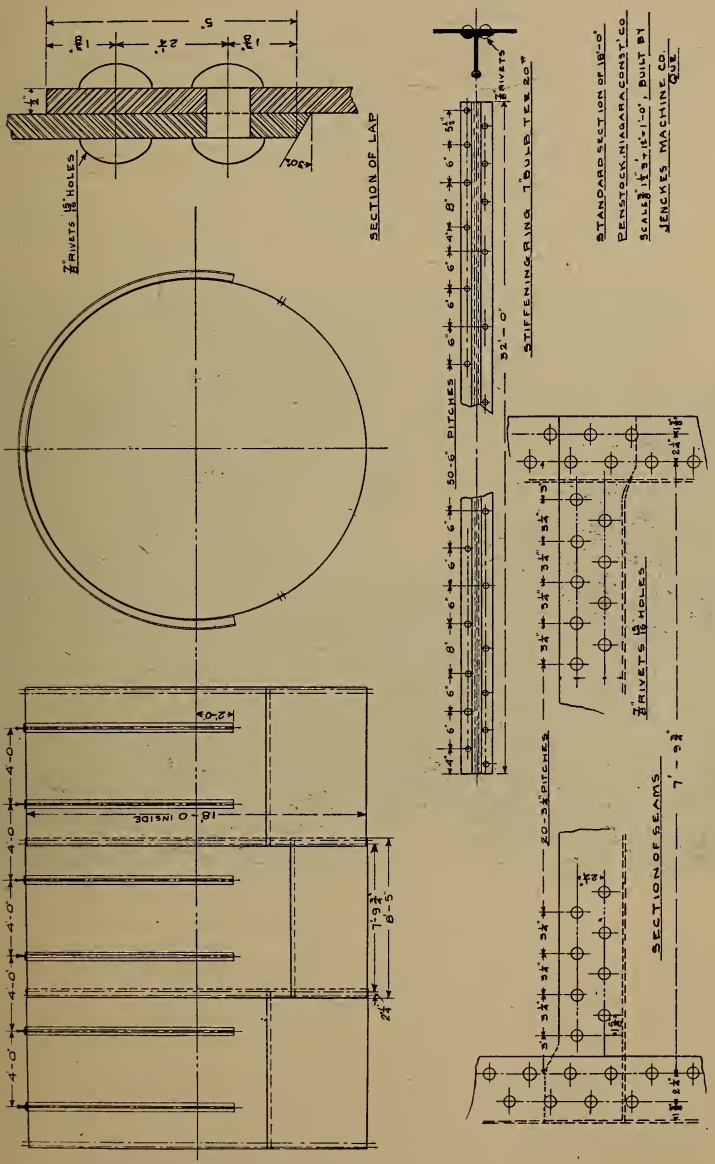
was useless and the 8 in. very little better. The 10 in. gave the best results, and even these were unsatisfactory, as they were continually blocking and filling with clay and silt.

The sheets, having been swung into the ditch, rested on 4 in. x 10 in. x 12 in. wedges, which were placed on 12 in. x 12 in. timbers 8 ft. long, spaced 8 ft. apart and tied together at the ends with plank. In order to balance the 30 ft. boom on the derrick as it swung over the trench, it was necessary to place a heavy weight on the bull wheel.

Before this weight was placed the derrick was on one occasion precipitated into the ditch, bending several sheets and causing considerable damage. Very little difficulty was experienced in assembling the plates and keeping to line and grade on the tangents; but on the curves, of which there were five, each of 800 ft. radius, there was often considerable trouble. The tendency of the curves, which were constructed of plates of special section, was to flatten, or in other words to creep away from the centre of curvature. Usually in a curve of a length of 400 ft. it would be necessary to put in two or three straight sections, to counterbalance this tendency. The plates, when assembled and bolted, were brought to line by jacks braced against the sides, and as the timbering was always set about 3 inches below grade, the blocking brought it to proper elevation with very little trouble.

It might be well to give a fuller account of the design of the pipe. As has been said, it was a cylinder 18 ft. in diameter made up of sections 8 ft. in length, each section consisting of three plates with double riveted lap joints. The plates were $\frac{1}{2}$ in. steel. The rivets were $\frac{7}{8}$ in. for 15/16 in. holes, with $3\frac{1}{4}$ in. pitch, and staggered. Each 8 ft. ring or section was reinforced over the top and down to 2 ft. below centre line, with two 7 in. bulb tees, each 32 ft. long, weighing 20 lbs. to the foot and spaced 4 ft. centres. At the bottom the rivet spacing on these was 2 in., increasing to 6 in. at the top, riveted on both sides of the flange. As soon as a few plates had been bolted up and before the tees were placed it was necessary to put in upright shores in each section to prevent distortion, caused by the weight of the plates. These shores were 8 in. x 8 in. hemlock or pine, 18 ft. long, and were placed by first bringing the section to a diameter of 18 ft. with a jack and post, and then fitting in the shores snugly. The sides were also drawn in with 18 ft. rods, having thread and nut on each end, these being put through rivet holes, horizontally, and drawn up with a wrench.

After the stiffeners had been placed and all rivets driven, the rods and a number of these shores were taken out, a few being left at distances of about forty feet to prevent further distortion, which it was feared might result from the completion of the earth fill.



THE ONTARIO POWER COMPANY'S PENSTOCK.

The bolting up and shoring completed, all the holes were faired by a reamer driven by compressed air, and as fast as reamed were blocked with rivets, by pneumatic riveting machines. These machines in the hands of skilled workmen drove and finished on an average from five to seven hundred rivets per day. One gang on one occasion drove upwards of 1,000 rivets in ten hours, which was a feat probably never before accomplished, except perhaps on boiler riveting, where rivets are much smaller, and conditions are much more

LOWERING PLATE TO BOTTOM OF TRENCH.

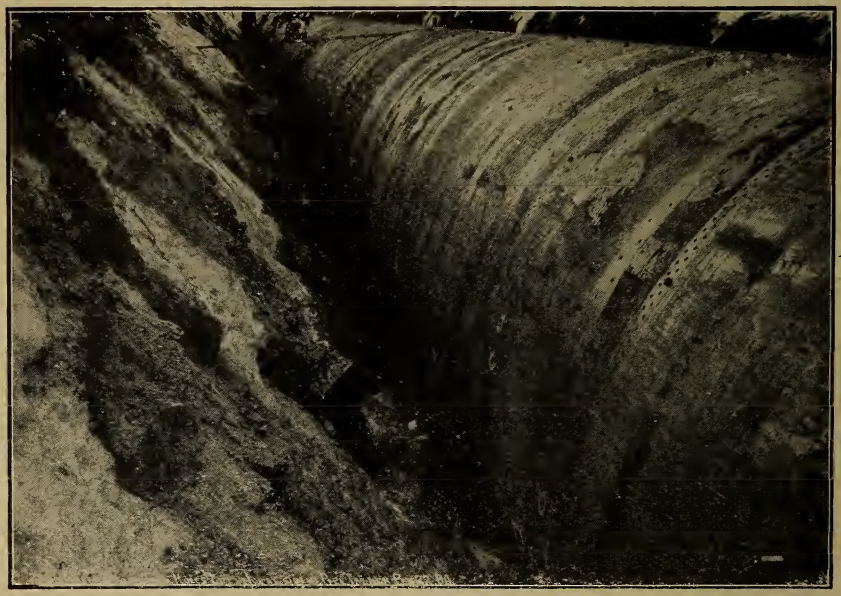
favorable. As only 1½ ft. was allowed below grade of pipe for working, all the bottom rivets were driven from the inside. From where the bulb tees began, up over the top, the rivets were driven from the outside. The fitting, bolting and riveting of the bulb tees occasioned most trouble, as these were usually considerably warped and twisted. The joints of the plates were made with a double row of ⅞ in. pan-head rivets, spaced 3 in. and staggered, with 5 in. lap. One section fitted inside the following section, and where overlapping seams made

a bulky joint, the corners of the sheets affected were flattened. Finally the whole joint was battered into shape with a striking hammer having a round head. The longitudinal seams were staggered alternately. All seams were caulked on the inside and afterwards tested by hose and force pump to see that they were water tight. Manholes were placed about 1,000 ft. apart to permit of access to the pipe after completion. These were elliptical castings 18 in. x. 24 in., with a cast iron cover, bolted thereto. The whole was surrounded by a cylindrical wrought iron hood, 3 ft. in diameter and 3 ft. high, with wrought iron cover. Both casting and cylinder were riveted to the pipe. A 10 in. relief valve was afterward placed in each manhole to admit air while the pipe was being emptied.

The pipe was then thoroughly sand blasted outside and inside preparatory to painting. The method used was to make the sand blasting machine portable by clamping a narrow gauge track to the bulb tees on top of the penstock and placing the machine on this, the air for the blast being supplied from the compressed air line. A similar operation was carried on inside the pipe, except that the track was laid on the bottom. The sand blasting of the tube was a very trying operation, and was perhaps the hardest on the men throughout the entire work. The steel was then given three coats of paint, the first of red lead, the remaining two of a black water mixed graphite paint. This checked on the outside and blistered on the inside badly, and on the whole was not altogether satisfactory. The first intention was to surround the pipe by a concrete jacket only in the rock cuts, while in the earth cuts earth fill was to be used. The idea was that as there would be no blasting in the earth cut, the steel would undergo no damage when the other two pipes would be installed, while in the rock cuts, where heavy blasting would occur, the pipe would require protection.

The first filling was begun about midway of the pipe. The earth here happened to be a heavy clay mixed with sand, and a large quantity of water was used in tamping it to place, a large hose being allowed to play upon it as the steam shovel did the filling. About 1,200 ft. had been filled when a distortion was noticed within the pipe

at the bottom, extending for a short distance. Fearing that this might extend, it was decided to stop the back-filling and surround the remainder of the conduit with a concrete jacket. The distortion was probably caused by excessive wetting of the clay, which, on excavation from about the injured section, was found to be in a semi-liquid condition. The consequence was that when this liquid mass collected under the pipe and the heavy fill came on it from above, the wall of the trench refused to give, and all the stress fell on the



RIVETERS WORKING IN HOLES CUT IN ICE AT SIDE OF PIPE.

unprotected side of the pipe. In the earth cut from grade of ditch to grade of pipe, a mixture of one of Lehigh Portland cement to ten of gravel was used. From grade of pipe to centre line the mixture was one to sixteen, and from centre line to top, one to eight. The concrete envelope was nowhere less than one foot in thickness. Concrete was placed in the ditch to a level four ft. below the centre line of conduit. Above this, forms were employed. An extra heavy arch of a thickness of 30 in. was used where the penstock is crossed by

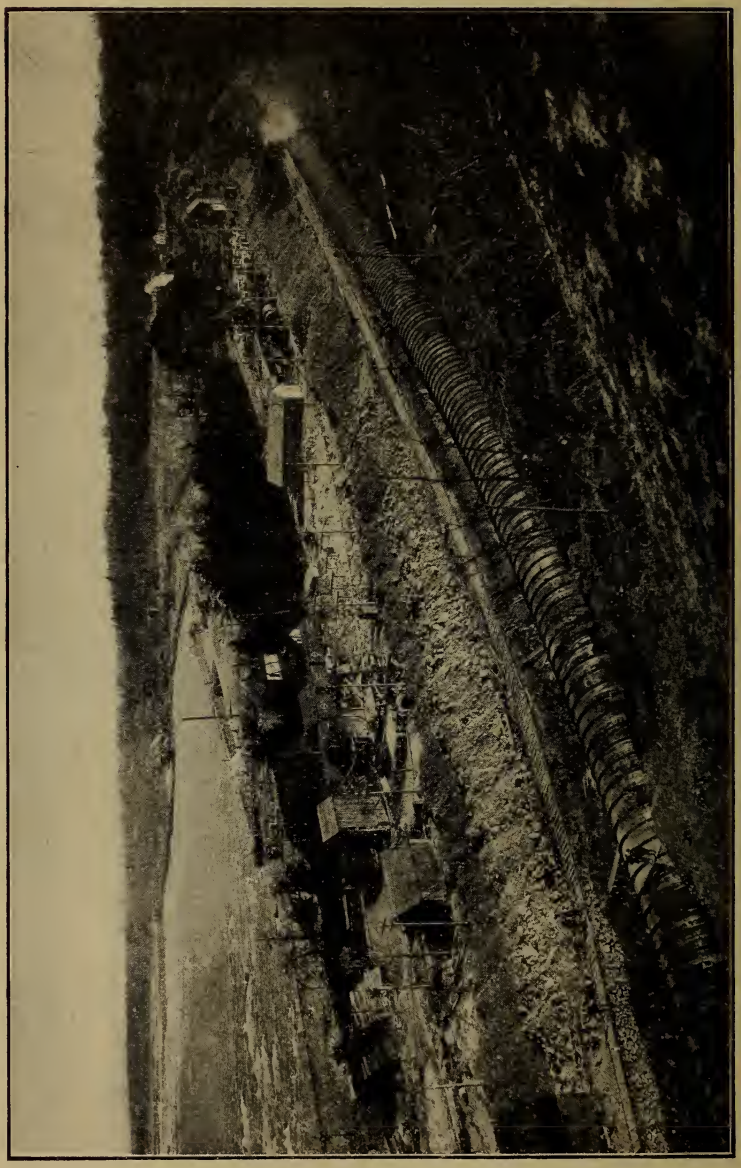
the electric railway tracks, and an extra stiffener was placed on each alternate plate.

On account of the weight of the steel, the section when placed and riveted was not a perfect circle, but was flattened somewhat at the bottom. This was not sufficient to make any appreciable difference in the area of the cross section, the maximum shortening of the vertical diameter being only 5 in.

Where the conduit meets the head block in the Dufferin Islands, it is joined to a concrete thimble. This thimble from a circle of 18 ft. diameter at the pipe changes to a square of 20 ft. to the side where it meets the gates. Owing to the proximity of the Niagara Falls Park and River Railway tracks, some provision had to be made to collect the ground currents returning to their power-house, in order to prevent electrolysis of the steel. A $\frac{1}{2}$ in. copper wire was laid along the top of the pipe and connections made with each plate by a $\frac{3}{8}$ in. braided copper wire. The main wire lies a foot below the finished grade of the ground and is connected to the N. F. P. & R. Ry. ground returns at their power-house.

The construction of the pipe began in the fall and proceeded throughout the winter. Then in the spring, as a considerable portion had been laid, temperature measurements were taken each day to ascertain what effect the heat was having. Hubs were placed on each side of the conduit at right angles with and at accurate distances from the centre line. In this way the beginning, centre and end of each curve were accurately referenced. Every day a party went over these points and measured the elongation and lateral movement. For a difference in temperature of 66 degrees, 2,400 ft. of pipe lengthened $7\frac{1}{4}$ in. It was found that the pipe had a rolling motion also, due no doubt to the unequal heating of the top and bottom and also to the difference in the quantity of metal between the inside and the outside of the curve. For a difference of temperature of 23 degrees the maximum roll was found to be 7 ins.

After these movements had been noticed for a short time, some of the upright shores which had been left in the penstock for bracing, especially on the curves, were found to be crushing at the ends and



LOOKING SOUTH FROM FALLS VIEW.

in some cases splitting and buckling. This was accounted for by the action of the stiffeners, which, when heated, acted in the manner of spring bows, tending to flatten the pipe. Doubtless, also, the alternate contraction and expansion of the steel shell assisted in producing the phenomenon observed. The greatest temperature noted on the top of the pipe at midday, with the sun shining, was 126° F., and at the bottom 96° F. From this can easily be seen one of the reasons for a rolling motion on the curves. With the pipe covered,

LOOKING SOUTH. PIPE NO. 1 BELOW FALLS VIEW.

however, and containing water, the maximum variation in temperature from winter to summer will probably not exceed 40°.

The pipe grades were as follows:—

430 ft. at.....2.09%.
3,880 ft. at.....0.25%.
1,788 ft. at.....0.51%.
310 ft. at.....0.00%.

This makes in all a fall of about 28 ft.

It might be interesting here to say that the elevation of water in the fore bay is about 557 ft. above the sea level, and the elevation of the river below the Falls is about 342 ft. This gives a head of 215 ft. The calculated loss of head from friction was between 22 and 23 ft. From the tests which have so far been made, but which are by no means decisive, the loss will apparently fall much below this, probably to about 16 ft.

LOWERING PLATE TO PLACE.

In the construction of the pipe, there were some 5,000 tons of plate and bulb tee material used, and something over one million rivets were driven. All of the material was furnished under special test and inspection, and the utmost care was exercised throughout the work continuously, not only in the rolling mills, but in the shop and the field, even to the painting and sand blasting. It is probable that the remaining two pipes will be constructed of reinforced concrete.

NOTES ON PUMPING CONDITIONS AND LIMITATIONS.

W. S. Pardoe, '04.

The question, "What are the limitations of pumps under different conditions?" is one to which approximate answers only can be given. The reason is that though definite results have been obtained from pumps working under known conditions, still the chances are very great that the one under consideration has some modifying influences, which alter the calculations slightly and therefore leave the result an approximate one, though of course correct enough for practical purposes. These remarks might be applied to any installation of machinery, but in the case of pumps they are particularly applicable. It is surprising to find how many are the causes which affect the satisfactory performance of a pump. It is often the case that a customer who has apparently employed every effort to locate the trouble complains of the poor action of a newly purchased machine. Eventually it transpires that some little detail which, to a great extent, changes the working conditions, has been neglected. A case in point comes to my mind. A man who had bought an independent air pump and condenser complained of the poor vacuum that he was able to obtain. There was much correspondence over the matter, and when at last a man was sent to try to discover the trouble, it was found after testing the pump for the usual causes of trouble, such as a leaky suction, insufficient source of supply, etc., that the owner had neglected to pack the pump piston.

I shall now endeavour to take up the conditions under which some of the different styles and classes of pumps work satisfactorily and will give first of all some of the general laws which govern all pumps.

In the first place there is the suction lift. The height to which water will rise with a perfect vacuum and the barometer standing at a pressure of 14.7 lbs. is, as is doubtless known, about 34 ft. It is impossible, however, for a pump to lift water by suction as high as this, for the reason that a perfect vacuum cannot be obtained on account of clearances in the pump, leakage of air in the suction pipe, and the excess of vacuum between the plunger and suction valves, over that on the suction side, which is necessary to overcome the resistance of the springs. This resistance is a necessary evil in order that these valves on the return stroke of the piston shall close quickly and thus prevent the return of water to the suction pipe. As an integral part of the total suction lift, must be included the equivalent head due to loss by friction in the suction pipe, in elbows and in the foot valve where this happens to be part of the equipment. These losses are dependent respectively on the diameter of the suction pipe, the number of elbows and the free inlet area of the foot valve. When the velocity of the water reaches 200 feet per minute, the friction becomes recognizable, and for further additions to this velocity, increases enormously. It is evident, therefore, that it is necessary to have the suction pipe of such a size and the elbows of such a number that these losses will not amount to a figure, which, when added to the actual lift, will make a total greater than the pump can handle properly. Most pump catalogues contain tables showing the friction loss per 100 ft. of length of pipe, so that it will be unnecessary to go more into detail on this part of the subject. Let it be said, however, that it is better to put in a pipe which figures a little large rather than one figuring a little small. If the latter be done, the speed of the piston at the beginning of the stroke may be such as to leave the water behind. The partial vacuum produced results in quickened velocity of the water, which, when suddenly arrested by filling up behind the piston, causes the disagreeable "water hammer" so injurious to the pump. This, though trouble enough in itself, is the source of additional annoyance, for the reason that one cannot be sure that there is not some other cause for the unsatisfactory working. The consequence is that, especially in the

case of long suction pipes, which would be expensive to take up and replace, every other known means to remedy the evil is tried. The annoyance and expense in all probability would have been avoided if in the first place some liberality in figuring the size of the suction pipe had been exercised.

Another feature which is necessary in some cases is an air vessel. Its location is a matter of some consequence. An air vessel on the suction would doubtless improve the working of any pump, but it is not necessary to have one in all cases. It is only when the suction pipe is very long that the air chamber is indispensable. The reason is at once apparent. The momentum of a long column of water, no matter how small the diameter, is a thing to be reckoned with, and manifests itself by the water hammer it causes on the reversal of the pump piston. If an air vessel is placed near the pump, it takes care of the differences in speed between the pump piston and the water in the pipe by allowing the water to flow into the air vessel where it is cushioned by the air at the top. This air will be compressed as the pump piston slows down, and by expanding will help the water to follow the piston when the latter is increasing in speed. According to the results of a number of tests published in the Proceedings of the A. S. M. E., the air vessel should be placed at the extreme end of the flow of water if at all possible, and not simply at the top of the upright column of water leading to the pump. As the leakage of air into the suction pipe materially affects the running of the pump, the kind of pipe connections must be considered. In ordinary small pumps whose suction is 6 in. and less, they are generally made of wrought iron, and if carefully put together can be made perfectly satisfactory. If the size is greater than this it is customary to use cast iron, and where the pipe is short, it is better to use flanged connections, as the difference in cost between them and those of the hub and spigot style is trifling for short distances. At the same time the former are much more satisfactory, for the reason that with the latter, care has to be taken that all the turns, etc., are well supported to prevent any movement which might cause the joint to open slightly and allow air to enter. Where flanged fittings are

employed, the pipe is, of course, practically immovable, and where, as is often the case, they lead through basements and overhang in wells, it is easily seen that their self-supporting qualities come in very useful. Where suction pipes are lengthy, the intervening pipe between the pump and well can be made hub and spigot with satisfactory results, as it can be well supported by the earth. The last length next the well and in addition where the pipe enters the building can be made with one end flanged, and thus flanged fittings may be used from these points outward.

While speaking of the suction pipe, it might be well to mention a point which occasionally turns up, and on which customers often have incorrect ideas. This is in connection with the control of the quantity of water pumped by throttling the suction. A little reflection will show that such control is derogatory to the smooth running of the pump for the reason that as the quantity of water entering the pump is not sufficient to fill the pump barrel, there is, at the beginning of the return stroke of the piston, nothing between the piston and the water. With full steam pressure behind it, the steam piston starts forward with great velocity and is stopped with a shock on coming in contact with the water. To sum up, then, with regard to the suction pipe, we observe the following:—The height that the water has to be lifted must be figured as the difference between the level of the water in the well and the level of the discharge valves in pumps whose suction decks are below the plungers. In the case of pumps whose suction decks are above the plungers, the height will be from the level of the water in the well to the level of these suction decks. In all cases to this height must be added the head in feet equivalent to the friction loss due to flow. This total height is generally placed, as a limit, at 25 feet for working conditions, and with this height everything must be in first class order. The suction pipe must be as tight as it is possible to make it; elbows must be avoided as much as possible, as they are the cause of great loss by friction; suction valve springs must not be too stiff, and in cases of long suction pipes, air vessels must be placed in the most favorable positions.

Another element is the speed at which pumps may be run. The speed depends primarily on the area of the suction and discharge valves, but another factor in this part of the question in ordinary direct acting pumps, is that of wear and tear. A pump running slowly under steady working conditions will last much longer and pump, in the aggregate, much more water than one running quickly. The shock, sudden reversals, etc., tend soon to destroy the machine when exceeding the ordinary speed. This on an average might be placed at 75 feet per minute for pumps of 500 gallons capacity and over, and correspondingly less for pumps of less capacity. Of course it is understood that I am here referring to the ordinary trade pump. Large waterworks pumps and special pumps are often designed for a much higher velocity, and on the contrary, boiler feed pumps, particularly, frequently run much slower.

The discharge from a pump can be treated much more independently than the suction, as the conditions controlling it are themselves more easily controlled. The prime requisite is that an air vessel of ample capacity be placed next the pump, the object being the reverse of that in the case of the suction air vessel. The former serves to change an intermittent flow of water (corresponding to the varying speed of the piston) to a steady flow, whereas in the suction vessel its duty is to change the uniform flow to an intermittent one. The size of the discharge pipe is an important point in long pipes, for the reason previously given, viz., that the friction causes a loss of pressure at the end of the main. This of course is easily gotten over in the case, say, of a steam pump, by increasing the steam pressure to such an amount that the water pressure at the pump is greater than that at the end of the pipe by a quantity equal to the loss due to the friction in the pipe, between the two terminals. This, as will be readily seen, is at the expense of the coal pile, and often in a short time will amount to a figure which would easily have paid for a larger size of pipe. The consequence is a loss which is directly traceable to the doing of unnecessary work in discharging water through a pipe whose small size causes a great deal of friction.

In the discussion of special types, I shall begin with boiler feed pumps. In this class of pumps, the limit of suction lift, in addition to the conditions already given, is determined by the degree of heat of the water to be pumped. If cold, there is nothing of course unusual in its operation, but if hot the limit of lift is determined by the temperature. The reason for this can be readily seen if one considers the case, for instance, where the water is at a temperature of 212 degrees. This is its boiling point under normal conditions, the vapour or steam arising from it being at a pressure equivalent to that of the atmosphere. In consequence a vacuum will be impossible, and the water will have to flow into the pump by gravity. Other and lower temperatures affect the suction lift proportionately, and as these relations are known quantities, it can always be figured what is the maximum temperature allowable in the water, supposing that the height of lift is fixed and *vice versa*.

This is therefore one of the problems to be dealt with in placing a boiler feed pump, and care must be taken to allow a margin above what is theoretically necessary to allow for steady working of the pump, as unforeseen events may arise which may raise the temperature of the water and render the feed pump inoperative. The piston speed of the pump is very slow, usually from 15 feet per minute for the smallest pumps to about 50 feet per minute for the larger ones, these slow speeds being found most suitable for the steady and constant work to which they are subjected. They are often used in connection with receivers, whose duty it is to regulate the quantity of water pumped by the amount to be pumped. This is done by means of a float in the receiver, which is connected by means of levers, etc., to a throttle valve on the steam pipe. The float falls as the level of the water in the receiver is lowered, and in so doing cuts off the steam to the pump and hence lowers its speed. It might be noted in this connection that trouble has arisen by the throttling lever having its position changed in relation to the float, thus allowing the pump to keep in action after the water has fallen to its lowest allowable level. The pump with steam pressure on, immediately begins to race, and as there is no water in the barrel it has no resistance to encounter. This continues for a little while until a gush

of water enters the receiver, when the pump has its regular duty to perform and resumes its normal speed. The fact that the pump races one minute and slows up the next is the puzzling point to the owner.

Power pumps are of many different types—simple, duplex, triplex, etc., as in steam pumps, but their limitations are more marked in the case of steam pumps. Take a duplex power pump for instance with a heavy geared wheel working into a pinion on a motor shaft, and assume a reversal of stroke takes place. The mass of water flowing into the barrel of the pump and following the pump piston in its stroke, is suddenly stopped and its motion reversed. The momentum of the wheel and armature in the meantime tends to start this column off in its changed direction at once, the consequence being that greater shock is experienced than in the case of direct acting steam pumps, whose impelling force, practically alone, is the elastic steam behind the steam piston. These remarks apply to crank and flywheel pumps as well, the flywheel taking the place of the gear and armature. In this style of pump a builder can afford to put the larger amount of material, increased valve area, etc., necessary to counterbalance the shock, for the reason that he knows the customer is willing to pay for it. In ordinary trade pumps, however, the easiest way to overcome the difficulty is to keep the speed slow, and thus combine a moderate amount of metal, and of work, with a correspondingly low price. The speed is also limited by the fact that the gears can stand only a certain pressure on their teeth when running at a certain velocity. This pressure and speed vary with different styles of teeth, such as wooden cogs, cast iron, steel, rawhide, etc. Noise is also an important factor in the running of this class of pumps, and it is necessary to so speed the machine that protests from near-by residents may not have to be met with. Increase of speed also beyond certain limits in large machines causes vibration in the foundations and this is transmitted to surrounding houses, resulting in deterioration of buildings, and leaving the pump owner liable to damages. Air vessels of large capacity have a marked bearing on the smooth running of this class

of pumps, especially in the case of single power pumps, where the discharge is far from uniform. Care should always be taken to place them as near the discharge deck of the pump as possible. To sum up, slow speed is necessary in power pumps, first in order to prolong the life of the pump itself, and secondly to make less miserable the lives of its owner and those in the immediate vicinity.

Condensers are of two principal classes, the "Jet" condenser and the "Surface" condenser. The barometric condenser is a type of what is ordinarily known as the Jet condenser, the difference between the two being principally the fact that in the latter the pump takes care of the condensed steam, cooling water and air, and in the former the pump supplies only the cooling water. The ordinary vacuum obtained is that equivalent to about 25 ins. of mercury, and in some large plants runs up to about 27 ins. With steam turbines a higher vacuum is attained, and the vacuum generally guaranteed is 28 ins. of mercury, while in some cases it reaches 28 1-2 ins. This result is generally achieved by the addition to the ordinary condensing apparatus, of a single or double stage dry vacuum pump, which exhausts the air from the condenser independent of the water. This is an efficient type of machine designed with a minimum of clearances, and it is aided in its work in many cases by passing the air on its way to the pump through a number of tubes over which the circulating water is passing. This has the effect, by lowering the temperature of the air, of reducing its volume and thus of allowing the pump to rarefy it to a greater degree. In the case of jet condensers, it is the vacuum in the column itself which draws the injection water to meet the incoming steam, and as in the case of an ordinary suction on a pump, the diameter and length of the pipe, as well as the height to which it has to be lifted, are the limiting conditions. Supposing that the injection pipe is of sufficient size to reduce the friction to an inappreciable amount, then the limit of length for safe working conditions is about 500 feet, and that for height is about 20 feet. In cases where these figures must be exceeded, it is necessary to allow the water to flow by gravity to a well to which the injection pipe is connected direct.

The condenser is an example of a case where the injection water, though being acted on by exactly the same force as is the water in the suction pipe of a pump, does not need an air vessel. In this case it does not have to contend with the varying speed of the pump piston, but is acted on by a uniform force and can flow in a steady stream without interruption. The inlet to the condenser is of fixed size, though of course may be adjusted, and therefore allows the water to pass its opening at a uniform rate.

The speed in this style of pump is also preferably kept low, say in average sizes, 70 feet per minute, as, in a jet condenser the pump barrel only half fills with water. The consequence is that the first part of the stroke is very rapid, and the greater the speed, the greater the shock when the piston strikes the water. The shock, however, is not as great as one would naturally expect, as a cushion of air interposes itself between the piston and the water. Still for easy working and long life a slower speed than even the one mentioned is desirable. The vacuum obtained is dependent on the size of the pump relatively to the size of the engine, on the tightness of the joints, and on the temperature of the injection water and the hot well. One can hardly see a connection at first thought between the temperature of the hot well and the vacuum in the condenser, but this is understood on considering the fact that the overflow from the condenser, or in other words the hot well, has a temperature entirely proportional to the vacuum in the condenser, so that if a greater vacuum is desired it can be had only at the expense of cooler water in the hot well. It is therefore an open question whether there is any gain in economy by increasing the vacuum over 27″, and lowering the temperature of the feed water entering the boiler. Of course the greater the vacuum, the more powerful is the engine, and that in a great degree.

Single-acting condensers are of a more efficient type than the duplex, and much more satisfactory in their working. With the duplex type a slight difference in the packing of the piston rod will cause one side to short stroke, and this, besides being wasteful of steam necessary to run the pump itself, is also conducive to greater

clearances in the pump body, and therefore less effective in producing a good vacuum. There are remedies in detail of construction for this fault, but at the best they are not as satisfactory as in the single type, where one can, if the load on the engines is steady and consequently the speed of the pump uniform, so adjust the reversing tappets that the clearances are as little as practically possible.

Turbine pumps are coming into great favour and supplanting the old centrifugal pumps in a great measure. Their efficiency has been much improved by a study of the shape of the vanes, by the introduction of guiding vanes in the body of the pump, by experimenting to find the most suitable ratio of diameter of impeller, velocity of water in the pump, velocity of impellers, and other such details. They are easily adapted to different heads by changing the number of stages, and thus can readily meet the great number of different conditions. The limit of pressure to be pumped against is, however, considerably less than reciprocating pumps; for though not theoretically, they are practically so on account of the great number of stages necessary for high pressures. For this reason a reciprocating pump is much better for distinctly pressure purposes. These pumps will not lift water without having their suction pipe first filled with water, but when once started they are capable of lifting the water by suction as high as and even higher than a reciprocating pump.

In the preparation of the above paper, the valuable assistance of Mr. E. R. Clarke, Mechanical Engineer, 16 Concord Ave., Toronto, is hereby acknowledged by the writer.

TURBINE STEAMERS.

M. R. Riddell, '04.

It is now ten years since steam turbines were first tried in place of reciprocating engines for the propulsion of ships: and during that space of time upwards of thirty vessels of all types except the slow-speed cargo steamer have been fitted with the turbine. It is therefore possible at this date to draw from experience with these vessels some conclusions as to the suitability of the turbine for this purpose, and also as to what class or classes of vessels it is specially adapted. The advantages claimed by its promoters for the marine steam turbine are briefly these:—

(1) Increased economy in steam consumption.

(2) Increased speed owing to lighter displacement made possible by the comparative lightness of the turbine machinery.

(3) Absence of vibration.

(4) Reduction in the amount of overhauling and repairing necessary, also of ordinary attendance, which makes possible a reduction in the engine room staff.

(5) Considerable reduction in the amount of lubricants and general stores required.

(6) If it be desired, considerable reduction in the space occupied by the engine room in the vessel.

(7) Lower centre of gravity of engines, giving increased stability.

(8) The adaptability of turbine machinery to powers and speeds of rotation (as in fast torpedo boat destroyers), at which piston engines become constructionally impossible, on account of weight, or of inertia stresses.

(9) The property possessed by the turbine of maintaining the original economy obtained, on account of the absence of rubbing surfaces, which in time affect the economy of a reciprocating engine by wearing, such as valves, valve seats, etc.

(10) In the case of naval vessels, the turbine machinery can be more conveniently housed under the armoured deck, and if stray shells or splinters happen to penetrate into the engine room there is less to be readily injured than in a ship with reciprocating engines.

(11) The small size of propellers, necessary on account of the high speed of rotation, while in most cases considered as a disadvantage, may, in shallow draft vessels, be an advantage, enabling better immersion of the propeller to be obtained.

The difficulties met with in applying the turbine to marine propulsion, and the main points that the opponents of the system have urged against it, are:—

(1) The difficulty of designing a satisfactory propeller for high speeds of rotation.

(2) If standard speeds of rotation and standard propellers are adhered to, the turbine becomes practically impossible, on account either of excessive weight or of low economy, or of both.

(3) The low steam economy of turbines at low speeds.

(4) The fact that turbines are not directly reversible, as reciprocating engines are, necessitating the fitting of additional turbines for going astern.

(5) The difficulty of manœuvring turbine vessels, especially when starting from rest.

These difficulties and objections are now to a large extent overcome, and an account of the methods and devices adopted to overcome them would form a history of the marine steam turbine.

In order to lead up to a discussion of the difficulties met with in applying the turbine to marine propulsion, it may be well to give a short account of the first turbine vessel, the experimental yacht "Turbinia."

In 1894 the Marine Steam Turbine Co. was formed for the purpose of developing the Parsons Steam Turbine as a method of marine propulsion. This turbine had already met with considerable success when applied to the driving of alternators. The first step taken was to build an experimental vessel, the "Turbinia," 100 ft. long, with 9 ft. beam, and a displacement under trial conditions of 44½ tons. The first preliminary trial was made on November 14th, 1894, and during the two succeeding years many alterations and thirty-one trials were made.

At first a single compound turbine, similar to those used for driving alternators, was fitted, driving one shaft. Seven different arrangements of propellers were tested, beginning with a two-bladed propeller of 30 inches diameter and 27 inches pitch. This gave the excessive slip of 48.8%. A four-bladed propeller was next fitted, and gave similar unsatisfactory results. Next an arrangement of several propellers on the same shaft was tried, the propellers being placed about three diameters apart. The best results were obtained with a set consisting of three propellers of 20-inch, 22-inch, and 22-inch pitch respectively, all having the same pitch to diameter ratio. With this arrangement the R.P.M.'s were 1,780, the per cent. slip 37.5 and the speed 19¾ knots. Nine different sets of propellers in all were tested, and the results compared with the power registered by a dynamometer, showed a very low efficiency of propeller.

The next step was to remove the original turbine, and replace it by three separate turbines, high, intermediate, and low pressure, each driving a shaft. The trials commenced again in February, 1896, with three propellers of 18 inches diameter, and one pitch ratio on each shaft, making nine in all. This arrangement gave satisfactory results. Several sets were tried and nine propellers of 24 inches pitch and 18 inches diameter were finally adopted as apparently giving the best results. The division of the turbine, thereby applying one-third of the power to each of the three shafts at once, together with a considerable reduction in the speed of rotation of the shafts, gave a great increase in propeller efficiency and speed. Roughly speaking, the propulsive horse power was about doubled by the change, so that

speeds up to 32 knots per hour were obtained. Arranged as above described, the vessel was, in April, 1897, placed in the hands of Professor Ewing, F.R.S., and a most careful series of trials was carried out by him on the speed and steam consumption.

Professor Ewing prepared a very interesting report on the performance of the "Turbinia," which was published as an appendix to a paper by the Hon. C. A. Parsons on the marine turbine. The maximum speed obtained, with the boiler pressure of 210 lbs. per sq. inch, was 32.76 knots. The steam consumption per propulsive horse-power hour at full speed was a trifle under 30 lbs., corresponding to a consumption of less than 15 lbs. per I.H.P. hour, if the usually estimated ratio of I.H.P. to propulsive horse power be assumed. The propulsive horse powers were carefully determined by experiments in a model tank. Professor Ewing also reported that, for her size, the "Turbinia" was a very good sea boat. High as was the speed of 32.76 knots obtained on these trials, it was surpassed in some subsequent trials on the Solent, after a larger steam pipe from the boiler to the high pressure turbine had been fitted, making the pressure at admission to the turbine 172 lbs. instead of 155 lbs., as in the previous trials. The speed attained on this occasion was upwards of 34 knots per hour, and is likely to remain a record for boats of the size of the "Turbinia" for some time.

Enough has been said in this brief sketch of the trials of the "Turbinia" to show that the real difficulty in applying the turbine to marine propulsion lies in the design of the propellers: and while anything like a complete discussion of propeller design is out of the question within the limits of this paper, a few remarks on the subject may be useful at this point. Practice in ship building is at this date so very much crystallized, that once the type, size, and speed of vessel (and consequently the I.H.P. required) are given, the R.P.M. and diameter, pitch ratio, and developed surface of blade of the propeller (or propellers, in the case of twin screws) are practically determined, the proportions employed by different shipbuilders probably not differing more than a few per cent. one way or the other.

The designer of propellers for reciprocating-engined ships, as will be seen by referring to the formulæ given in hand books on naval architecture, generally starts with the R.P.M. of the machinery, and consequently of the propellers, already fixed. He has enough data to hand from successful existing propellers to enable him, with the use of hand-book formulæ, to design a satisfactory propeller for each particular case. Now and then, however, a vessel designed in all respects according to the best standard practice, will fail to come up to expectations, and the trouble is in nearly every case with the propellers. The fact is that less is known with certainty about the best proportions for the propellers, and their action when the vessel is under way, than about any other point in the entire design. The reason for this is that most of our information with regard to propellers is derived from tank experiments. Such experiments are unquestionably of great value; but in the case of propellers they of necessity have the unfortunate defect that they do not reproduce the exact conditions under which a propeller works when driving a vessel. In a tank, a propeller works in practically undisturbed water. Behind a vessel the water in which the propeller works is always more or less already disturbed by the passage of the vessel. In a tank the water has perfectly free access to the propeller. This is not, generally speaking, the case when the propeller is driving a vessel, though in modern practice this point is so well attended to that usually very little loss of efficiency occurs from this cause, the "run" of the vessel being designed to allow the freest access of water to the propeller.

The point where the discrepancy between the results of tank experiments and the results obtained in service specially affects the question of the design of propellers for turbine vessels, is with respect to the best diameter for a propeller. The results of tank experiments seem to indicate that that propeller is best which discharges the greatest possible amount of water in a given time at the lowest possible velocity. From this it appears that a propeller to be highly efficient requires to be of comparatively large diameter; in fact, if it were not for the frictional losses in driving the propeller, and the phenomenon of "cavitation," the larger the diameter, allowing always

sufficient immersion, the better. If there were nothing in practice to offset this, then there would be very little chance of designing a satisfactory turbine vessel: because, while the turbine, in the light of its performances when driving alternators, might be expected to be rather more efficient than the reciprocating engine, the comparatively poor efficiency of the small propellers made necessary by the comparatively high rotational speed of the turbine, would more than counterbalance the gain in the machinery.

The limiting element in regard to diameter in propellers driven by turbines is the phenomenon of "cavitation." It has been found by experience that when the speed of the blade tip of a propeller much exceeds 12,000 ft. per minute, the water no longer perfectly follows up behind the blades, and cavities begin to form at the backs of the blades. Cavitation is also caused to some extent by attempting to obtain too much work per square foot of blade area. It is liable to occur whenever the thrust pressure per square inch of projected blade area much exceeds 13 lbs. As the thrust increases with the speed of rotation, the two causes occur more or less simultaneously with propellers of ordinary proportions. Cavitation is accompanied by a great loss of efficiency, as might be expected, and probably to a large extent accounts for the poor results obtained with the propellers in the early trials of the "Turbinia." The reason that cavitation never had to be seriously considered in the case of reciprocating-engined ships lies in the fact that to avoid excessive piston speeds the revolutions are kept comparatively low, except perhaps in torpedo-boat destroyer work, where much has to be sacrificed tc gain in lightness.

The losses in propellers are due to cavitation, friction, slip, and augment of resistance. Cavitation can be avoided by keeping the thrust pressure per square inch of projected blade area less than 12 lbs., or thereabouts; and as this area depends finally on the diameter, and as an increase of diameter such that the speed of the blade tips exceeds 12,000 ft. per minute, will itself tend to increase cavitation, it may be necessary to distribute the thrust required to propel the vessel over several propellers in the turbine-driven ship instead of the one or two common in ordinary marine practice.

Three propellers are usually found sufficient, but in fast vessels, where an unusually great thrust has to be developed, four may be necessary. In regard to friction losses, tank experiments seem to show that they vary nearly directly with the surface of the blade, and the square of the velocity at which this surface is driven. Hence, although the blade surface is made proportionately smaller for a given thrust in turbine work, the speed of rotation, and consequently of blade surface, being considerably higher, it is probable that greater loss occurs from this cause than in ordinary practice.

The slip in turbine-driven propellers is also probably greater than usual, under the same conditions of immersion, owing to the higher speed. But as the small diameter of the propellers enables better immersion to be secured, and increase in head of water over the propeller will decrease the percentage of slip, the slip under working conditions may be no higher than in ordinary cases. Experience also seems to show that the importance of this point has been overestimated, and that so long as slip (in a fast vessel) does not exceed 25%, the losses due to slip are not excessive. An advantage in fast running propellers, which turbine practice is able to secure, is due to the inertia or resistance to movement of water. The fast running propeller more quickly lays hold of new masses of water, and thus obtains a more effective thrust upon the water, with a less percentage of slip than might be expected.

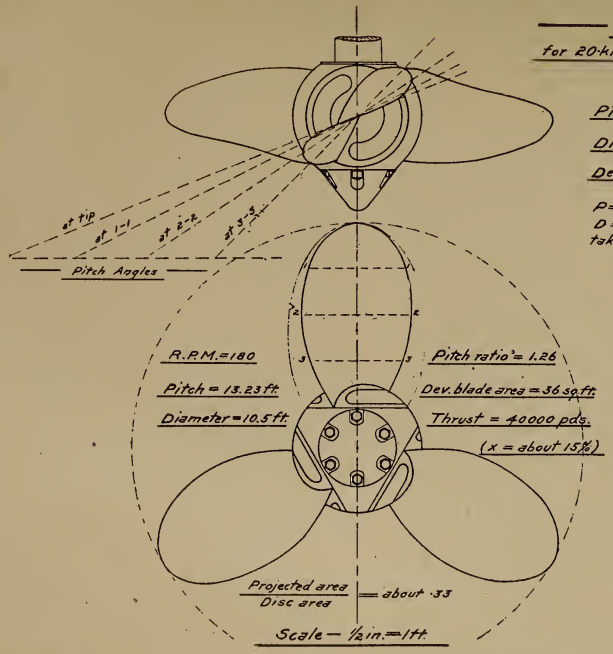
Augment of resistance is due to the propeller interfering with the water as it closes in around the stern of the vessel. As a ship moves forward she parts the water at the bow, pushing part of it to the right and part to the left. This produces a resultant pressure at the bow opposing the motion of the vessel. At the stern, again, the water will tend to close in, producing a resultant pressure in the direction of motion of the vessel. If the ship has what is known as a "fair" form, that is, if she is not too blunt at the ends, the pressure at the bow is balanced by the pressure at the stern under ordinary circumstances, and little or no perceptible total resistance is produced from this "stream line action"—which must not be confounded

with the phenomenon of wave making—at ordinary speeds, supposing the vessel to be towed. The propeller interferes with this stream line action, and causes a reduction of pressure on the stern of the ship. This is the same thing in effect as an increase of pressure at the bow, and the resistance to the ship's motion through the water is "augmented." This loss is sometimes as much as 40 or 50 per cent. increase upon the resistance of the ship when towed at the same speed, according to Mr. Froude, who investigated the subject. In turbine work this loss is materially reduced owing to the smaller diameters of the propellers.

Taking two vessels, the "Manxman," a Midland Railway steamer, driven by turbines, and the "Ulster," a Holyhead mail boat of similar speed and power, the total disc area of the propellers of the "Ulster" is 226 square feet, while that of the 'Manxman" is 86 square feet.

If the thrust deduction is proportional to the area of the disturbance of the stream lines, the effect on the "Manxman" will be far less than on the "Ulster." The effect however depends to some extent on the intensity over the disturbed area, this again being modified by the nearness of the propellers to the sides of the ship, which is generally less in turbine work. Altogether it seems probable that the loss due to augmented resistance is much greater in the case of the "Ulster" than in the case of the "Manxman." This fact of decreased augment of resistance probably explains why large propellers are not always superior to small ones in practice, and why it is possible, notwithstanding the necessarily small diameters of the propellers, to produce a turbine-driven vessel that will show a satisfactory propulsive efficiency.

The diameter of the propeller in practice more or less fixes the pitch (or the pitch the diameter if we start with the R.P.M.'s known). The ratio of pitch to diameter varies between 1.5 and .8 or .9. The reason why it cannot be made less than about .8 or .9 without reducing efficiency is that the most efficient part of the blade is that inclined to the axis at or about 45°, and it is therefore desirable to have this pitch angle occur as nearly as possible at the centre of effort of



TWIN SCREW PROPELLERS

for 20-knot Channel Steamer of 6000 Indicated Horse Power.

Formulae.

$$\text{Pitch in feet} = \frac{10133\,S}{R(100-X)}.$$

$$\text{Diameter in feet} = K\sqrt{\frac{I.H.P.}{\left(\frac{P\times R}{100}\right)^3}}$$

$$\text{Developed area of blades in square feet} = C\sqrt{\frac{I.H.P.}{R}}.$$

P = pitch in feet : S = speed in knots : R = revolutions per minute.
D = diameter in feet : x = %age of apparent slip : K & C are coefficients taken from the following table.

(From Seaton and Rounthwaite Hand-book)

Propeller Coefficients.

Description of Vessel.	Approx. speed in knots.	No. of Screws.	No. of Blades per Screw.	Values of K.	Values of C.	Usual Material of Blades.
Bluff cargo boats	8–10	One	4	17.–17.5	19.–17.5	Cast Iron
Cargo, moderate lines	10–13	"	4	18.–19.	17.–15.5	" "
Pass.& mail, fine lines	13–17	"	4	19.5–20.5	15.–13.	C.I. or S.
" " " "	13–17	Twin	4	20.5–21.5	14.5–12.5	" " "
" " very fine "	17–22	One	4	21.–22.	12.5–11.	G.M. " B.
" " " "	17–22	Twin	3	22.–23.	10.5–9.	" " "
Naval vessels " "	16–22	"	4	21.–22.5	11.5–10.5	" " "
" " " "	16–22	"	3	22.–23.5	8.5–7.	" " "
Torpedo-boats	20–26	One	3	25.	7.–6.	B. " F.S.

C.I., cast iron ; G.M., gun metal ; B., bronze ; S., steel ; F.S., forged steel.

TWIN SCREW PROPELLERS.

the blade. If the pitch were made very fine, this pitch angle would occur too near the boss of the propeller and the efficiency would be reduced. If the pitch were made coarser than about 1.5, too much of the blade is effective only in producing rotation of the water, with little propelling effect, and again the efficiency would drop. The best pitch ratio is found in practice to lie between 1.1 and 1.5. In turbine design, .9 to 1.0 is generally employed, with as high as 1.3 in torpedo boat destroyer work.

In regard to width of blade, the tendency of late years in reciprocating-engine practice has been to increase the ratio of projected disc area from the .2 of Froude's screw to about .33. In turbine work, in order to gain enough blade surface with small diameter, this has been increased to from .5 to .56. Experiments recently carried out in the model tank at Washington seem to show that the efficiency remains practically constant over a considerable range in width of blade; but beyond about .58 the blade interference becomes excessive, and to gain a larger area a larger diameter must be used. If this is not practicable owing to the blade tip speed, the required blade area must be distributed among a greater number of propellers. The best form of blade is a matter of opinion: but a form much used is the ellipse. In the case of turbine propellers, in order to gain area the minor axis is increased above the .4 or .5 times the major axis, common in ordinary practice, so that the blades become practically circular in shape.

From what has been said, it will be evident that it is hopeless in turbine work to assume the R.P.M.'s and then try to figure a suitable propeller. The first step must be to determine either from experience with similar ships, or from tank experiments, the thrust of propeller required to propel the ship at the designed speed. Then, taking into account the desired thrust per square inch of projected blade area—usually from 9 lbs. to 12 lbs. in turbine work as against 5 lbs. to 8 lbs. in reciprocating-engine practice—and the ratio of projected to disc area, the diameter can be found. From this, using the desired pitch ratio, and making an allowance for slip that experience has shown to be about what is to be expected, the pitch is determined, and the R.P.M.'s for the turbine.

Again, from experience, the point where it does not pay to further reduce the R.P.M.'s of the turbine will be known; and, taking this into account, the number of shafts and propellers necessary to develop the required thrust without employing proportions of propellers that have been shown to be inefficient can easily be found. Generally, for speeds up to 25 knots three shafts are found sufficient: above this it may be advantageous to employ four. Having settled on the thrust required, and the number and proportions of the propellers, attention can now be given to the turbine.

The forms of turbines that have been tried are the Parsons, the Rateau, and the Curtis. Practically, discussion is limited to the Parsons, as the Rateau and Curtis turbines fitted have been on small experimental vessels, chiefly torpedo boats. Curtis turbines are also being tried in a cruiser building for the U. S. Navy, and a channel steamer building by the Vulcan Co. at Stettin, Germany. The Parsons type of turbine has been on the market for 12 or 15 years now, and is generally well known, there being, including marine installations, upwards of 1,000,000 horse power in use. As applied to marine propulsion the turbine is usually divided into three separate turbines; the high pressure turbine driving the central shaft and two low pressure turbines of equal size driving the wing shafts. By this arrangement a good propulsive efficiency can be secured for the propellers without abnormal dimensions at the low pressure end of the turbine.

A discussion of the theory of the Parsons turbine is impossible in the space at disposal, but a few of the considerations affecting the design for marine purposes may be mentioned. Expanding through a definite range of temperature and pressure steam exerts the same energy whether that energy be taken up by moving blades, as in a turbine, or expended against a receding piston, as in a reciprocating engine. Two transformations of energy occur in either case, first from thermal to kinetic energy; secondly from kinetic energy to useful work. The Parsons turbine consists practically of a series of reaction turbines similar to those used in hydraulic power plants. Each stage consists of a row of fixed blades which are attached to the casing, and a row of moving blades, attached to the rotor. A certain

pressure drop occurs at each stage, the thermal energy corresponding to the drop appearing as kinetic energy, which is imparted to the buckets or moving vanes, and by them transformed into useful work in driving the rotor against the load. There is, of course, a certain loss due to friction and eddying, just as in water turbines.

The laws governing the best theoretical relative velocities of steam and moving blade are similar to those for water turbines, but in practice the best ratio is a matter of opinion. The ratio of blade speed to steam speed in marine work has varied from .37 to .51, from .45 to .5 being most commonly employed. These ratios are important, as they determine the angles of exit and entrance of the blade, and also the theoretical efficiency of the turbine as a hydraulic motor. With the smaller values of the ratio the efficiency is theoretically reduced, but there may be some gain in other directions in any particular case that will, in practice, cause the smaller value to be adopted as preferable. The form of the guide blades and the moving blades is the same. The energy of the steam corresponding to its temperature and pressure at admission to the turbine is in foot pounds, B.T.U.'s $\times$ 778. This corresponds to the head in water turbines. Neglecting friction and eddying losses, and using the equation $V = \sqrt{2g\ (H_1 - H_2)}$ the velocity of steam corresponding to the use of 1 B.T.U per row would be about 223 ft. per second. With velocity of blade to velocity of steam = .5 this would correspond to a blade speed of about 112 ft. per second.

Suppose from propeller calculations it was found necessary for the turbine to have a speed of 600 R.P.M. (a speed about that used in channel steamers). Taking 112 ft. per second as the average speed of the blade—that is, the speed at half height of the blade—the circumference of the drum at this point would require to be 11.2 ft. or the diameter about 3 ft. 7 in. The speed of rotation of the shaft could be reduced in several ways:—

(a) A lower value of the blade speed to steam speed ratio could be employed.

(b) The diameter of the drum could be increased.

(c) A smaller amount of heat energy could be used per row.

The first method would involve too great a sacrifice of efficiency, in most cases, for any considerable reduction of the rotational speed of the shaft. The method is, however, sometimes used in the low pressure turbines. The second method would involve a great increase in weight, and, moreover, there is a point for any given power beyond which the diameter cannot be increased without a serious loss of efficiency for a reason that will be discussed later. The third method would involve a very long turbine, taking up too much room in the ship just where room is very valuable; and as the steam friction losses increase with the length of the steam path and with the square of the speed of the steam flow, approximately, there must be some point beyond which any increase in length would mean reduced economy owing to increased losses from this cause.

The blade speeds commonly used in practice in the high pressure turbines, in marine work, vary from 70 to 80 ft. per second in ocean steamers, to from 110 to 130 ft. per second in torpedo craft. In the low pressure turbines the speeds are 110 to 130 ft. per second, and 160 to 210 ft. per second respectively. There are usually from 80 to 90 rows on each turbine. In designing a turbine for a required power, no such convenient formula as $\frac{PLAN}{3300}$ can be used; but for a given size of turbine, the particulars of the blading to be used being known, the steam consumption per horse-power hour will be pretty well known from experience, and the turbine will be designed to take the required amount.

The rate of flow of steam to be used, and the volume required in a given time, will determine the space between the drum and the casing, and consequently, for a given diameter of drum, the blade height. There are other considerations affecting this question of blade height, however. The clearance between the tips of the moving blades and the casing, and between the tips of the guide blades and the drum of the rotor, cannot be made indefinitely small owing to the expansion of the rotor and casing due to the temperature, which, moreover, is not constant along the turbine, but may fall over two

hundred degrees in seven or eight feet, from the high pressure end to the low pressure end, causing considerable distortion of form. This clearance in marine work varies from .02 to .1 inches, .02 inches being probably the minimum allowable.

It has been found that if this clearance much exceeds 1/50 of the blade height the leakage losses over the tips of the blades are excessive. This leakage over the tips of the blades is not detrimental so much on account of the actual leakage loss, though of course this has to be considered, as on account of the superheating effect on the steam leaking past the more or less sharp edges of the blade tips upsetting calculations as to width of openings required at different points of the turbine, by increasing the steam volume. This would seem to fix the minimum length of blade desirable at about one inch. Again, with blades over about six or seven inches in length, the bending moment on the blade becomes excessive, and also the average width of the openings between the blades. A rule that has been used in practice is to make the height of blade at least three per cent. of the mean diameter of the drum. This question of blade height explains why, for a given power, the method of decreasing the speed of rotation by increasing the diameter of the rotor cannot be carried further than a certain very definite limit in practice. It also explains why it is only in fast vessels, or on those small classes—such as steam yachts—where some propulsive efficiency can be sacrificed to gain in other directions that the Parsons turbine can be satisfactorily fitted.

In slow cargo vessels the power required is not sufficient to enable a height of blade that will avoid excessive blade tip leakage losses to be adopted, and at the same time the speed of rotation to be kept low enough to secure good efficiency of propellers. The only way to get over the difficulty would be to employ an excessively long turbine, which would be undesirable on account of the extra cargo space monopolized in this case for the machinery, as well as the comparatively low efficiency of turbine due to large steam friction losses. Low pressure, however, might be used, necessitating a sacrifice of the economy which attends the use of high pressure steam. Either

method would be commercially inadmissible. In regard to weight, it is roughly estimated that this varies inversely as the square of the revolutions in the Parsons turbine. With the other types—Rateau and Curtis—to gain the same low peripheral speeds with low powers, the weight increases even more rapidly, it is said, and the steam efficiency is very poor. From experience, it would appear that the turbine cannot be satisfactorily used for speeds under 16 knots per hour. Professor Rateau, in a paper describing the installation of Rateau turbines in some experimental torpedo boats, places this lowest advantageous speed for turbine vessels at an even higher figure, 20 knots per hour. Good results have, however, been obtained with Parsons turbines down to about 16 knots per hour.

The actual figuring out of a turbine is an exceedingly complicated calculation, as allowance has to be made for the leakage over the blade tips, the superheating effect of this on the steam, the effect of the heat generated by steam friction, causing evaporation of moisture, and possibly superheating, the final volume being greater than would be the case if the expansion were purely adiabatic. If good results are to be obtained, however, the calculations of volumes must be carefully made. At low pressures the volume per pound of the steam is much greater than at high pressures, and if a uniform diameter of drum were used throughout the turbine, the blades at the low pressure end would be inconveniently long. Hence, in land turbines, the diameter of the drum is increased by steps.

In marine turbines the same diameter of drum is used throughout in each turbine: the high pressure turbine extends to the point where further increase in length would make the blades too long; after leaving the high pressure turbine, in the general arrangement of three shafts, the steam flows through two low pressure turbines in parallel, the necessary increase in steam space being thus obtained without abnormal dimensions of blade or drum. In the arrangement of these shafts the proportions of the turbines are made such that about $\frac{1}{3}$ of the available energy of the steam is used in the high pressure turbine, and $\frac{2}{3}$ in the two low pressure turbines. In most vessels the low pressure drums have been made of the same diameter,

or nearly so, as the high pressure drum, and either a higher speed of rotation or a lower value of the ratio of blade speed to steam speed adopted. This is done to save in weight. In the "Carmania," however, the low pressure drums are much larger than the high pressure drum, and the saving in weight is therefore comparatively little over the reciprocating engines in her sister ship the "Caronia." A better propulsive efficiency, and a coarser pitch for the propellers is, however, obtained than would be possible if the ordinary practice were followed. This is expected to enable her to make better time in rough weather, as experience on the Atlantic has shown that very fine pitched propellers do not give very good results with head winds and head seas.

Owing to their high rotational speeds, turbines have to be most carefully balanced, both statically and dynamically, as even a small lack of balance would cause unpleasant vibrations while a larger amount would be dangerous. In the case of the "Carmania," not only were the turbines balanced statically and dynamically, but the same treatment was applied to the shafts and propellers. The result of this exceptionally careful balancing has been an absolute absence of vibration in running.

The astern turbines in the Parsons system are now generally placed at the rear end of the low pressure turbine, and when the vessel is going ahead revolve idly in vacuum. In their design a smaller ratio of blade speed to steam speed is used to enable greater compactness to be attained, though at some loss of efficiency. With the Parsons turbine, due to the action of the steam, an end thrust occurs in the direction of the propellers which is advantageously used in balancing the propeller thrust. This reduces the necessary size of thrust block, and thrust block friction losses. The thrust is in practice not entirely balanced and a small thrust block is fitted at the forward end of the turbine casing, being usually part of the casing. The after end of the casing is secured to the hull of the vessel. The forward end is allowed to slide forward under the longitudinal expansion when hot, and takes with it the entire shafting. In large turbines great care has to be taken in "warming up" before

using, to avoid differences of expansion of rotor and casing, which might destroy axial clearances and cause stripping of blades. The bearings are outside the casings and are fed with oil under pressure from an oil pump. The same oil is used over and over again, and consequently the consumption of oil for the bearings is small. The bearings for marine turbines are rigid and the pressure is so regulated that the product of pressure and velocity of rubbing in feet per second does not exceed 2,500 to 2,700. Under these conditions the wear of the bearings is negligible. Any wear on the bearings might produce blade stripping by destroying the clearance between blade tips and casing. Where the spindles pass out of the casings they are packed to prevent escape of steam or ingress of air. Owing to the temperatures, ordinary packing cannot well be used. The tightness required is secured by rows of brass Ramsbottom rings arranged in groups. Between the groups are spaces which can be put in communication with steam, so that the difference of pressure between the first and last rings of a group may not be too great. In the case of the low pressure end of the low pressure turbine the steam admitted between the groups of rings effectually prevents the leakage of air into the turbine, and enables the high vacuum to be maintained.

In manœuvring by means of the propellers alone steam is shut off from the central high pressure turbine, and admitted direct to the ahead or astern end of the low pressure turbines. The high pressure turbine revolves idly in vacuum. The admittedly inferior manœuvring qualities of the earlier turbine vessels were due to insufficient astern power; this has been overcome in later vessels. There is a point in regard to handling a turbine vessel that requires attention. In coming up to a dock it is usual to shut off steam from the engines some little way out, and allow the frictional resistance of the vessel and the drag of her propellers to bring her nearly to rest. Then the engines are reversed when just at the dock, bringing the vessel finally to rest. In the case of a turbine vessel, if the steam be shut off at the same distance from the wharf, the speed will not be nearly so much reduced by the time the wharf is reached, as

the brake action of the propellers is practically nil, the turbines revolving almost frictionlessly in vacuum after the steam is shut off. It will be necessary to reverse the engines sooner therefore, in order to bring the vessel to rest at the wharf. Inattention to this has sometimes caused a turbine vessel to run into the dock at which she was arriving, as for instance the "Turbinia" at Toronto on May 24, 1905, ran 8 feet into the cribbing at the end of her slip before she could be stopped. The injury sustained, however, was trifling.

From the preceding remarks on propellers and turbines, it will be seen that in any particular case there may be necessary some give and take between the turbine and the propeller. Thus, to avoid too great loss of efficiency, or excessive weight in the turbine, a higher speed of rotation may have to be adopted than is consistent with the best propeller efficiency; and again, to avoid too great propeller losses, some efficiency or some saving in weight on the turbine may have to be sacrificed.

Experience with the land turbines shows that in units of the size and power of marine turbines employed, the relative efficiency will be about 65%. In marine turbines it may perhaps be a little less. The recent experiments carried out in the Washington model tank show that with propellers of the proportions ordinarily employed in turbine work, the efficiency may be somewhere about 70 per cent., with average slip.

Having shown the nature of the problem that confronts the designer of a turbine vessel the results obtained in practice with some different classes of vessels will now be considered. The success of the "Turbinia" called the attention of the British Admiralty to the speed possibilities of the turbine, and they ordered a destroyer afterwards named the "Viper" to be fitted with Parsons turbines. The dimensions, 210 ft. long, 21 ft. beam, and about 370 tons displacement, were the same as employed in 30-knot destroyers with reciprocating engines. The speed required, however, was 31 knots.

The "Viper," with full trial weights on board, and a displacement of 370 tons, attained an average speed of 36.581 knots on a one hour's full power trial, the highest speed being considerably over

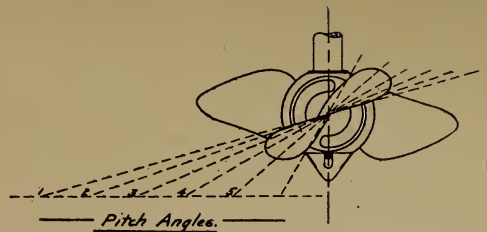
37 knots. At all speeds there was an almost complete absence of vibration. The guaranteed astern speed of 15½ knots was realized. In the "Viper" four shafts were employed with two propellers on each shaft. The high pressure turbines drove the inner shafts, the low pressure turbines the outer shafts; to the same shaft as the low pressure turbine, there was attached a small reversing turbine which revolved idly in vacuum when going ahead. The weight of the turbines, with condensers, pumps, shafting and propellers, was about 73 tons, the power corresponding to the speed obtained being about 12,000 I. H. P. In the 30-knot reciprocating-engined destroyers, the corresponding weight for the same details is 80 tons, and the I. H. P. 6,500.

A larger class of destroyer, with reciprocating engines, of which H. M. S. "Albatross" may be taken as a type, had about 115 tons weight of machinery with 9,500 I. H. P., the speed actually attained being a little short of 32 knots. The steam consumption of the "Viper" was slightly less for the same power than in the other vessels. The "Cobra," similar to the "Viper," built for stock by Armstrong, Whitworth & Co., was purchased by the British Government when her trials showed results equally good to those obtained in the "Viper." Both these vessels had unfortunately very short careers, the "Viper" running on a rock while scouting at high speed in a fog during the naval manœuvres, and the "Cobra" breaking her back in a heavy sea on her first trip. Careful enquiry showed that the loss of neither vessel could be charged to the turbine machinery, yet the unfortunate loss of these vessels certainly delayed the adoption of the marine steam turbine in other vessels.

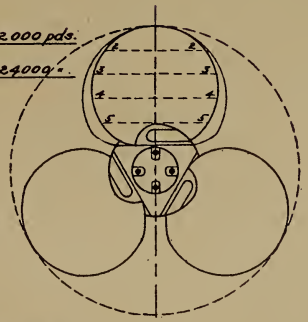
The next vessels built with turbines were the "King Edward" and "Queen Alexandra" for service on the Clyde. The "King Edward" attained a speed of 20.5 knots, and the "Queen Alexandra," which was built about a year later, and embodied some improvements suggested by the performance of the "King Edward," made 21.43 knots. It was stated by her builders, Messrs. W. Denny and Bros., that had the "King Edward" been fitted with the best type of triple expansion machinery, the highest speed that could have

been realized would have been 19.7 knots, as against the 20.5 actually obtained. These vessels have proved most satisfactory in service, the steam consumption being less than 15 lbs. per I. H. P. hour, and the average coal consumption over a whole season's running less than 1.8 lbs. per I. H. P. hour. This includes coal for all purposes, pumps, lighting plant, heating, etc., as well as the main engines. The oil consumption was very low, the "Queen Alexandra" using only one barrel of oil in the whole season of rather more than five months. It is stated that the manœuvring qualities of these vessels left somewhat to be desired. This was probably due to the reversing turbines not being quite powerful enough. The "King Edward" appeared in 1901, the "Queen Alexandra" in 1902. The success of these boats caused orders to be placed for several vessels to be fitted with the Parsons turbine, among which were the channel steamer "The Queen" for the South Eastern and Chatham Railway Co., and the "Lorena," a steam yacht of some 1,500 tons, built at Leith on the Firth of Forth to the order of Mr. A. L. Barber, of New York. "The Queen" was built by Messrs. Denny in 1903, and is 310 ft. long, 40 ft. beam, and 25 ft. deep. She attained on her trial a mean speed of over 21.73 knots going ahead and an astern speed of 13 knots. When travelling at full speed the vessel was brought to rest in 1 minute, 7 seconds, travelling in this time only two and one-half times her own length.

On the channel service between England and France, "The Queen" has given complete satisfaction, and contrary to the predictions of some authorities, makes even better time in rough weather than her sister vessels on the route fitted with reciprocating engines. The "Lorena" was fitted with turbines similar to those in the "King Edward," but the speed for which she was designed was only 16 knots. By employing turbines instead of reciprocating engines a saving of 70 tons in the weight of the machinery was made possible. On her speed trials the "Lorena" maintained for five hours an average of over 18 knots, the machinery running with the utmost smoothness, and the steam and coal economy being very high. On



Pitch Angles.



Thrust (total) = 72000 pds.
" (per propeller) = 24000 "
a = 113.0
p = 103
m = .57
K = 666.7
Diameter = 6 ft.
Pitch ratio = .9
Pitch = 5.4 ft.
R.P.M. = 485. (x = about 22½%)

Scale – ½ in. = 1 ft.

TRIPLE SCREW PROPELLERS

for 20-knot Channel Steamer with turbines of 6000 equivalent I.H.P

Formulae.

$$\text{Diameter in feet} = \sqrt{\frac{\text{Thrust in pounds}}{K}}$$

$K = a' \times p \times m.$

a' = area in sq. ins. of circle one foot in diameter.

p = thrust pressure per sq. in. of projected blade area.

m = ratio of projected blade area to disc area.

Pitch in feet = diameter in feet × pitch ratio.

pitch ratio for turbine propellers varies from .8 to 1.5.

$$\text{R.P.M.} = \frac{10133\,S}{P(100-x)}$$

P = pitch in feet

S = speed of ship in knots.

x = %age of apparent slip.

her trip across the Atlantic the vessel behaved very well; the propellers did not race even in heavy weather, and the turbines ran admirably without the slightest hitch. Several other turbine yachts were built about this time, one of which, the "Tarantula," is remarkable in that she is modelled after a British first-class torpedo boat. Her machinery was similar to that of the "Turbinia," but in addition a cruising turbine was fitted to increase the economy at speeds under 15 knots. She was of 150 tons displacement, and attained a speed of 25.36 knots. She is now owned by Mr. W. K. Vanderbilt, of New York.

About this time further experiments with the "Turbinia" showed what had been suspected by some naval authorities, that the arrangement of three propellers on each shaft was not as efficient as one in which only one propeller on each shaft was fitted. The nine propellers as originally fitted were replaced by three, of slightly larger diameter, 28 in. and 28 in. pitch, with the result that increased speed was attained for a given power.

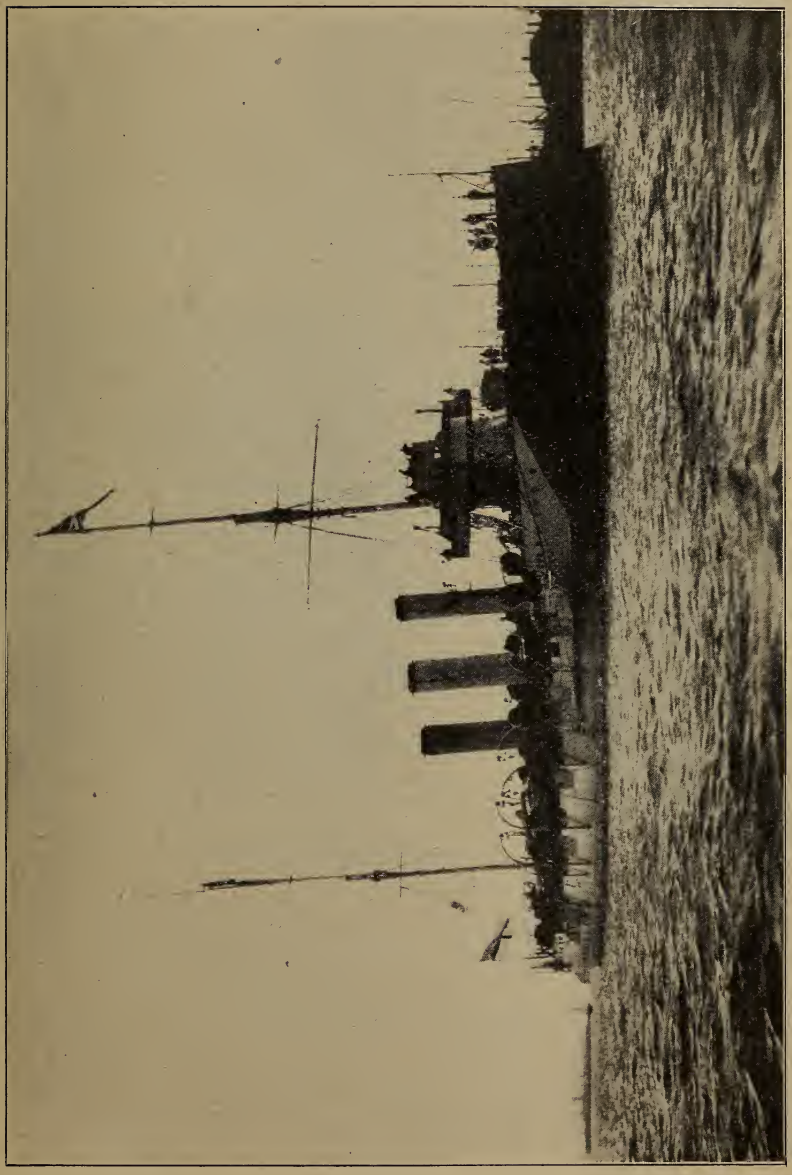
The objection to a number of propellers, one behind the other, in theory is that the first propeller is really the only one that gets a chance to work in fairly undisturbed water. The water reaching the two behind has been already disturbed to a considerable extent by the first propeller, and the efficiency of the hinder propellers is low. Moreover, with three propellers on a shaft, one of them is too near the hull of the vessel, and causes vibration. All turbine vessels built subsequent to these trials have one propeller only on each shaft, and those that had more than one propeller on a shaft originally, the "King Edward," the "Queen Alexandra," and the "Tarantula," have since had the extra propeller removed with beneficial results.

The British Admiralty acquired two new turbine destroyers, the "Eden" and the "Velox." The "Eden" was built for a moderate speed of 25½ knots; the "Velox" is a high speed vessel similar to the "Viper," but of greater displacement. She is fitted with two triple expansion engines of 150 horse power each, for use at low speeds, as well as turbine engines for high speeds, of upwards

of 10,000 horse power. When the reciprocating engines are in use they are connected to the shafts by a claw clutch. This is considered a dangerous arrangement; for if the engineers in charge forgot to throw the small reciprocating engines out of gear before speeding up to the higher powers an accident would be likely to happen. Then, as the engines are simply so much useless dead weight at full power, the slight increase in efficiency at low speed is too dearly obtained. The "Eden" has cruising turbines to increase the economy at low speeds. The arrangement used in the "Velox" has not been repeated. The Midland Railway Co., in 1903, ordered four vessels for the mail and passenger service between Heysham and the north of Ireland and the Isle of Man. Three of the vessels were alike, the "Donegal," "Antrim," and "Londonderry." The other, the "Manxman," was intended more especially for daylight service to the Isle of Man and was slightly broader than the other vessels. The "Donegal" and "Antrim" were fitted with four cylinder triple expansion engines of the latest type, and have proved extremely economical in service. The "Londonderry" and "Manxman" are fitted with turbines. In the "Londonderry" the steam pressure is only 150 lbs., as against 200 in the "Donegal," "Antrim," and "Manxman." The speeds attained on trial were 21.9 knots for the "Antrim," the better of the reciprocating engined boats, 22.27 for the "Londonderry" and 23.14 for the "Manxman." Both the "Londonderry" and the "Manxman" were more economical in steam consumption than the other boats, at all speeds over 14 knots—the "Manxman" considerably more so. The weights of machinery, engines, boilers, shafting and propellers are 730 tons in the "Antrim" and "Donegal," 575 tons in the "Londonderry" and 655 tons in the "Manxman." In regard to cost the "Londonderry" cost 1½% more than the "Antrim"; but if the "Antrim" had been fitted with engines to drive her at the same speed as the "Londonderry," she would have cost 10% more than that vessel. In one season's service the "Londonderry" and 'Antrim" were out about even as regards cost of running; but the "Manxman," speed considered, is considerably more economical.

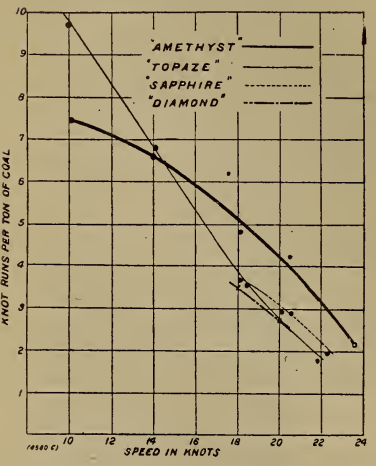
The two turbine vessels are preferred by the travelling public on account of the absence of vibration.

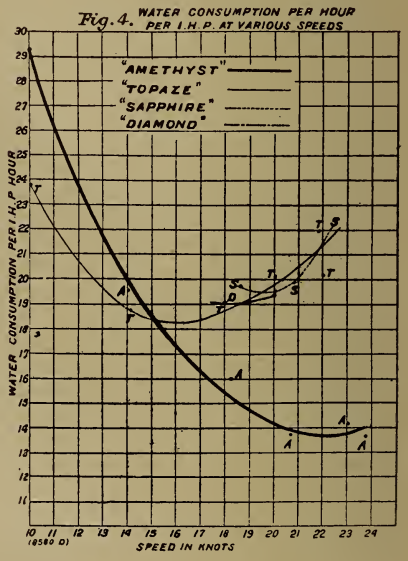
Perhaps the most convincing proof of the superiority of the turbine as regards economy has been given by the cruiser "Amethyst." Four small cruisers of some 3,000 tons, three exactly alike, the "Topaze," the "Sapphire" and the "Diamond," fitted with reciprocating engines, and one, the "Amethyst," fitted with Parsons turbines, were ordered in 1903 by the Admiralty, the specified speed being 21.75 knots. All the vessels exceeded this speed, the fastest of the reciprocating engined boats doing 22.34 knots and the "Amethyst," with the same boiler power, 23.65 knots—an increase in speed of 1.29 knots. This was gained with less pressure on the boilers and with 10% less coal consumption. Under 14 knots the steam consumption of the "Amethyst" was slightly higher than that of the other three vessels; but at 18 knots it was 20% less, at 20 knots 30% less, and at the highest speeds about 40% less. At 20 knots the coal consumption was 47% less, being 1.5 lbs. per I. H. P. for the "Amethyst," and 2.31 for the "Topaze." The weights of machinery were 537 tons in the "Topaze" and 535 tons in the "Amethyst." The power obtained from these weights was 9,800 I. H. P. in the "Topaze" and 14,000 I. H. P. in the "Amethyst." To increase her economy at low speeds the "Amethyst" had cruising turbines fitted. This accounts for her machinery weighing practically the same as the reciprocating engines in the other vessels. At low speeds the steam first enters two high pressure cruising turbines fitted one at the ends of each of the two side shafts; from this it passes to two intermediate pressure cruising turbines, one on each of the same shafts; from there to the main high pressure turbine on the central shaft; and finally to the two main low pressure turbines on the side shafts, and through them to the condensers. At high speeds the cruising turbines are cut out, the steam entering the main system direct. This arrangement of cruising turbines undoubtedly increased the economy at low speeds; but as the vessel was more economical than her reciprocating engined sister ships at all speeds at which it is likely she would be called upon to travel on



H.M.S. "AMETHYST."

active service without using the first two of the cruising turbines, it seems likely that such a complete system of cruising turbines is unnecessary and could profitably be modified, with some saving of weight. In the "Topaze" the lowest steam consumption per I. H. P. hour occurred at about 16 knots, being about 18¼ lbs. for main and auxiliary engines. At 18 knots it was 18.95 lbs. for main and auxiliary engines, or 15.45 lbs. for main engines alone. In the "Amethyst" the best economy occurred at about 20 knots, the con-





sumption for all machinery being only 13.8 lbs. per I. H. P. hour, or only very little over 10 lbs. per I. H. P. hour for the main engines alone. These figures are altogether exceptional, but there is no reason to doubt their accuracy, as they were obtained under service conditions on a carefully conducted Admiralty trial by experienced observers, and represent the average of an eight hours' run.

It is satisfactory to note that the good results obtained on trial have been verified in service. In fact, at low speeds better results have been got in service than were obtained on the trial runs, the

waste steam from the auxiliary engines having been turned into the low pressure receivers, as was done in the other boats on trial, instead of being led direct to the condensers, which was the arrangement adopted at first in the "Amethyst." With this change, the "Amethyst" has shown herself the more economical boat at all speeds down to 10 knots per hour. Again, it may be noted that she obtained these results with a vacuum of 27.8 inches; had she been fitted with "Parsons' vacuum augmentor"—a device which enables high vacuums of 29 inches to be obtained with ordinary proportions of air pumps, and which is being fitted in all the later turbine vessels, she would probably have done even better. In the face of such results as these it is not surprising that the British Admiralty have decided to adopt turbines instead of reciprocating engines on all classes of vessels for the navy.

The first turbine battleship will be the "Dreadnaught," launched a few days ago (February 10, 1906), which is to have a speed of 21 knots, as against the 18½ commonly adopted. Armoured cruisers are to attain 25 knots, as against the present 23; and turbine destroyers are building with a guaranteed speed of 36 knots, requiring an I. H. P. of 28,000—only a little less than that of the Cunarder "Campania." These increased speeds have been made possible not only without any sacrifice of actual fighting strength in guns and armour, but with actually an immense gain in these respects, by the use of the turbine.

Of recent channel steamers (up to the end of 1905) propelled by turbines, the fastest is the "Viking," of the Isle of Man Steam Packet Co.'s fleet, which has a speed of 23½ knots, and is the fastest turbine passenger vessel yet built.

About the time of the successes of the early turbine vessels the Cunard Steamship Co. had under consideration the construction of two immense trans-Atlantic liners of 25 knots speed. As the turbine seemed to offer advantages, naturally its merits were inquired into by the company with a view to its possible use in these vessels. The British Admiralty was also interested, as they guarantee a subsidy on these vessels in order that they may be available for war purposes.

A commission composed of some of the most prominent naval architects carefully investigated the question, their researches and experiments extending over six months. The report of this commission has been considered confidential, and has not been made public; but as a result of their deliberations it has been decided to adopt turbine machinery in these 25-knot vessels as offering great advantages over reciprocating engines. These vessels will have four shafts, the outer two being driven by the high pressure turbines and the inner by the low pressure turbines. The reversing turbines will be incorporated with these low pressure turbines according to the plan usually adopted. The power required in these vessels to develop the speed of 25 knots will be 68,000 I. H. P. The two vessels are well advanced in construction, one on the Clyde and the other on the Tyne, and will probably be ready for sea about the end of this year. Before these vessels were laid down the Allan Line decided to fit turbines in two new vessels building for them at that time, the "Victorian" and the "Virginian," of 12,000 tons. Both vessels have been running now for nearly a year and have given every satisfaction, the only unfortunate incident in their careers being the stranding of the "Victorian" on the St. Lawrence. Built for a speed of 18 knots, the "Victorian" achieved 19.5 knots on her trial, and the "Virginian" 19.75. They have not been pressed on service, but the "Virginian" has broken the record for the Canadian route. The saving of weight in these vessels by adopting the turbine is stated to have been 400 tons, and accommodation for 60 extra passengers is possible on account of the saving in space.

While deliberating on the construction of the 25-knot vessels, the Cunard Co. had ordered two vessels of about 20,000 tons and 19 knots speed for the Atlantic passenger trade, both from John Brown & Co., of Clydebank. It was intended to fit both with reciprocating engines, but Messrs. John Brown & Co. suggested that one of the vessels be fitted with turbines, as this would supply data for the construction of the turbines for the larger vessels, one of which was to be built at Clydebank, and would also afford good opportunity of comparing the performances of turbines and reciprocating

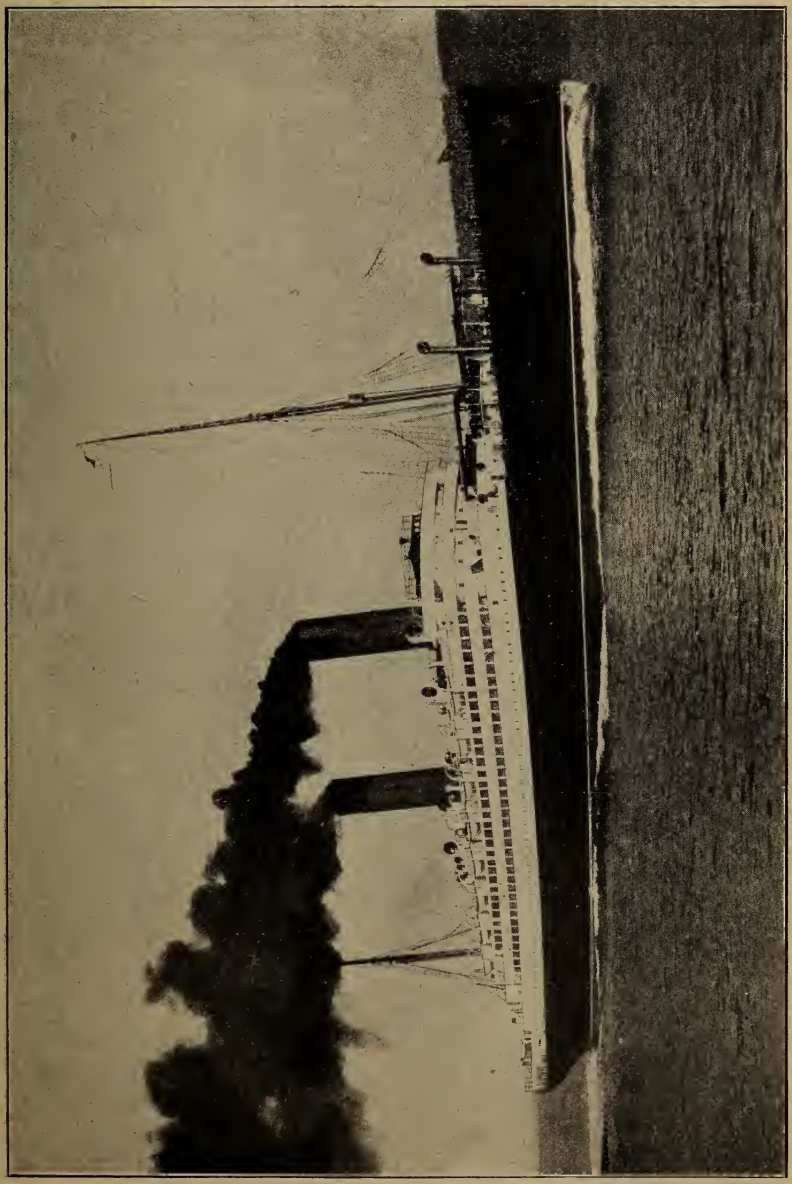
engines in similar ocean vessels. The Cunard Co. fell in with the idea, and the "Caronia" was fitted with reciprocating engines, the "Carmania" with turbines. The two vessels are exactly similar, with the exception of their propelling machinery, the "Caronia" being fitted with twin screws driven by two sets of quadruple expansion engines, with cylinders 39 in., 54½ in., 77 in., and 110 in. diameter by 5 ft. 6 in. stroke, and a boiler pressure of 210 lbs. per square inch. The "Carmania" has three shafts, the centre one driven by the high pressure turbine, the outside shafts by the two low pressure turbines, which carry also in their casings the reversing turbines. The boiler pressure used is 195 lbs. per square inch. The engines of the "Caronia" take the steam at 200 lbs.; the "Carmania's" turbines at 150 lbs. The "Caronia" on trial developed a speed of 19.5 knots, the "Carmania" 20.6 knots. Thus the "Carmania" was a knot faster with practically the same boiler power, this corresponding to a gain of probably 15% to 20% in the horse power developed. The saving in weight is only some 5% in the turbine vessel, but as explained before, to get a more satisfactory propeller for ocean service it was decided to forego the advantage of greatly decreased weight. The castings for the casings of the low pressure turbines in this vessel are probably among the largest ever made, the casings being 35 ft. long and upwards of 14 ft. in diameter. These casings, and in fact all heavy casings for marine turbines, are cast with stiffening ribs running both longitudinally and circumferentially to prevent as far as possible distortion of the shape when heated—this being a very important point, in view of the effect of such distortion on blade tip clearances. The weight of each of the low pressure turbines complete is 340 tons—certainly the heaviest turbines ever built. The weight of the low pressure turbines in the "Virginian" and "Victorian" is 78 tons. The power developed by the "Carmania's" turbines is probably about 25,000 horse power; the R. P. M.'s are 180. in the large 25 knot vessels this is to be reduced to 140. In regard to the question of vibration, the "Caronia's" machinery was balanced on the most approved system, yet a slight vibration was detected when under way; but in the case of the "Carmania" the most

delicate seismographic vibration recording apparatus failed to register any appreciable vibration in either the vertical or horizontal direction, this result being obtained by the accurate balancing of the turbines, shafts, and propellers. The pilot who took the "Carmania" down the upper reaches of the estuary of the Clyde from her builders, and who also handled the "Caronia" on a similar trip, states that of the two vessels the "Carmania" was the more easily steered, and as an instance of her manœuvring powers it may be stated that she was steered through the most intricate portion of the channel by means of her engines alone, owing to a slight temporary mishap to her steering gear.

If space permitted, many interesting details of the vessel and her machinery might be given; but it may at any rate be stated that there are 1,115,000 blades used in the turbines, each one of which had to be put in place, caulked, correctly set, and individually inspected. A number of other turbine vessels might be mentioned, among them the "Turbinia," which has run successfully between Toronto and Hamilton for two summers, but space will not permit.

In summing up it is evident, I think, from the performances of the vessels described above that the claims of economy and convenience made for turbine vessels have been abundantly justified in practice; and that the objections urged against the use of the turbine for marine propulsion, in the later vessels at least, have little foundation in fact.

As to the question of cost, it is probable that at present a turbine vessel is somewhat more expensive than one with reciprocating engines. The manufacture of the turbines requires special machinery, and exceptionally careful and accurate workmanship, if good results are to be obtained; but as turbines are turned out in larger numbers there is little doubt that the cost can finally be reduced below that of reciprocating machinery. The cost of up-keep will be much less in the case of the turbine, as there is practically nothing to wear out, and, owing to its comparative simplicity, accidents are less likely to occur with turbines than with reciprocating engines. In this connection it may be interesting to note that during the naval manœuvres of 1903,



S.S. CARMANIA.

under conditions which involved full speed steaming for long distances in heavy weather, out of 70 large vessels engaged, 12 were temporarily disabled by accidents to their machinery. None of these accidents were serious, but all were sufficient to compel the vessels to drop out of the respective squadrons with which they were travelling. Had they all had turbine machinery, eight of the mishaps could not have occurred at all, as they affected parts not found in turbine engined ships. For fast passenger vessels and for naval service the turbine seems to be an almost ideal motor from the point of view of comfort, speed and economy. For slow speed cargo vesels it is still not quite commercially possible, but further improvements may yet fit it for this service as well. There is certainly a great field for a turbine that can be constructed of moderate dimensions and weight, combined with good steam economy, and slow enough speed of rotation to enable good propeller efficiency to be obtained.

A FEW POINTS ON SWING AND LIFT BRIDGES.

L. R. Thomson, '05.

As a paper of this kind must above all things be exceedingly brief, I shall endeavour to call your attention to only a few points pertaining to swing and lift bridges. I am of course unable to claim the slightest degree of originality for this work, except that I have grouped in one short paper various well-known facts connected with the subject. The paper will be divided into two sections—1st, "Swing Bridges," 2nd, "Lift Bridges." After touching on these two, I shall close the paper by comparing the two distinct types.

Centre pier swing bridges are now of such common occurrence that in crossing over one we very seldom take into consideration the fact that in its design more thought is necessary than in that of three or four ordinary single span bridges. This fact may not be quite clear until one considers that even the simplest centre pier swing bridges have at least two spans, which are, in all probability, either continuous or partially continuous. The former term implies an arrangement of the trussing to insure full continuity of the bridge over the pier, and the latter, an arrangement of the trussing such that no shear is, or can be, transmitted from one span to the next. I will, however, touch on this point again.

There are two distinct classes of swing bridges — the classification in any given case being determined by the kind of support given the bridge at the central pier. The first method is called the centre bearing method and the second is known as the rim bearing method. In the former the turntable on which either the trusses or girders rest comes to a bearing

on a central pivot, which is, of course, very carefully stepped. As the whole of the dead weight of the bridge comes on this pivot, it is quite apparent that this method can be used only for small spans. In the alternative method of support, which is used for all heavy and large spans, the weight of the bridge is carried upon a set of small wheels, or rollers, distributed around the circumference of the turntable. By this arrangement, it is evident that support is given to the truss in two points, thus making each bridge a structure of three spans (two water and one pier), while in the former case the bridge is one of two spans only.

PLATE NO. 1.

We shall now direct our attention very briefly to the subject of "end support"—that is, the various methods in use of holding the ends of swing bridges in place. Until comparatively recently the ends of swing bridges were allowed to lie on their supports, one might also say loosely, thus causing one of the many evils of this system, known as "hammering." Suppose a live load to enter upon and cover the first span of a two-span swing. The deflection will, of course, force the free end of the other span into the air. As soon as the load has moved past the centre support, its weight will force the free end of the span down to its abutment with a sharp "bang." This is what is known as "hammering," and it is only possible

where there are "free ends." Needless to say, in modern practice this system is never adopted.

Another plan that is used to some extent is that known as the wedge lifted end method. Where this is employed, the two shore ends of the bridge are raised by wedges after the closing of the bridge, which, by this contrivance, can be made fully continuous for the dead load. These wedges are driven in a certain distance, which, of course, depends on the amount of "lift" that the ends require. The magnitude of this "lift" may be determined by some of the various well-known deflection formulæ. Having assumed a certain distri-

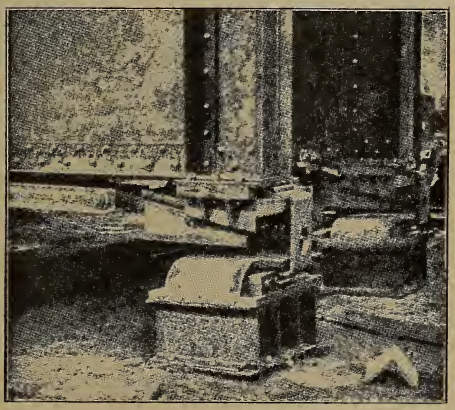


PLATE NO. 3.

bution of dead load, we can calculate the deflection of the ends, when the bridge is swinging freely over the centre. Now it is quite evident that if each end be lifted the amount of its deflection, there will be perfect continuity of the bridge for dead load. But as the ends may, under certain conditions, lift off their abutments, it is also quite evident that this method does not *insure* full continuity for the live load. Plate No. 1 shows the end wedge for a plate girder draw span, with connections to centre machinery. Plate No. 3 shows wedge in detail.

There is still another method of end arrangement to which Merriman gives his strong endorsement. This is known as the

"Locked End" plan. In this method there are heavy bolts, or pins, which lock the ends into position when the bridge closes, but which produce no reactions whatever between span and abutment under a purely dead load. Thus the dead load stresses are the same, regardless of whether the bridge be open or closed. The advantage of the system is seen when a live load comes on the bridge. The bolts, which admit of neither upward nor downward motion, will be able to take either positive or negative reactions. Thus the live load stresses are governed completely by the laws of continuity.

As to the relative merits of these systems, I can not do better than quote from Merriman. He says:—* "The first (loose ends) should never be used. The second method (wedged ends) should be avoided or used with great caution, while the third method (locked ends) may be employed as reliable both in theory and practice."

Now that we have touched on the various kinds of centre support, and the various kinds of end support, a few words as to superstructures in common use will be needed. Superstructures can, of course, be divided into two great classes, plate girder draw spans, and trussed draw spans. The former are always used for spans up to about one hundred feet in length, while the latter are employed for spans longer than this. Plate girder draw spans are nearly all of the converging flange type, although occasionally the bowstring type is used. The plate girder draw having a deeper web at centre has been found to be the most economical for the work required. In designing this bridge, the live load reactions are found by the principles of continuity (provided locked ends are used). The dead load is of course carried by the central pivot irrespective of whether the bridge be open or closed, the centre pier arrangements being such that all live load is taken off the central pivot. With regard to trussed swing bridges, there are several styles. They are, speaking generally, all of the rim-bearing type, and consequently bridges of three spans. See Plate No. 2 A. In it we observe that the pier span is made up of a quadrilateral with two diagonals. Suppose for the

* "Roofs and Bridges." Part IV., Higher Structures.

meantime that only one be present. It is manifest that the figure is perfectly rigid—because it is a frame-work connecting 4 points by means of *2x4—3=5 pieces. This assumes, however, that the diagonal can take both tension and compression. But the designing of such a piece is not convenient, hence two diagonals are placed in the frame, each designed to take tension and tension only. Now, we have proved that this figure is rigid. Therefore the panel in the bridge, represented by our figure, is rigid, and as such is quite capable of transmitting shear and of having bending movements. Consequently for this style of superstructure, the principles of continuity apply—provided, of course, that the diagonals are made heavy enough to do their work. Having shown that for this superstructure, the laws of continuous bridges apply, the design is begun by assuming some style of loading, and working out by various methods† the cross-sections of members of the bridge. Care must be taken not to apply to the solution of the problem, formulæ involving the assumption of constant moment of inertia and neglect of deflection due to shearing stresses resisted by web members.

From the completely continuous swing bridge to that known as the partially continuous swing bridge is a very short step. All that is necessary is to remove the two diagonals from the centre, or pier, span. This being done, the only connections between the two outside spans are a horizontal upper chord and a horizontal lower chord. By glancing at the central span, we observe that it is not rigid, because if any force, tending to produce either horizontal or vertical shear, be applied, the figure will certainly change its shape. In consequence, no shear can be transmitted from one side of this span to the other, because the span itself is not rigid. It is apparent, therefore, that the bridge can not be called continuous, because the elastic curve is not continuous over supports 2 and 3. See plate No. 2 A. In modern practice, however, when a partially continuous swing bridge is designed, the style of superstructure used is a combination

* A frame work is rigid when there are $2 \times N-3$ connecting links, where N=number of points in frame.

† Johnson's "*Modern Framed Structures*," Arts. 176 and 177.

of the Pratt and the Baltimore. See Plate No. 2 B. This type is the one most used for draw spans of the larger sizes. It is a type having no redundant members, and is also very economical. Those members shown in light lines take tension only; those in heavy lines may take either tension or compression. Those members in the tower shown dotted are only there for the purpose of stiffening the tower, and do not take any shear. The truss is therefore partially continuous. In reference to this, I may say that the longest swing bridge in the world was built with a superstructure of exactly this type. I refer to the 520 ft. swing span connecting East Omaha, Nebraska, with Council Bluffs, Iowa. The general dimensions are:—

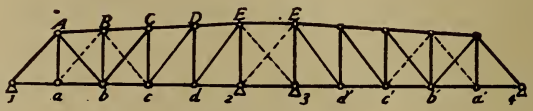


PLATE No. 2 A.

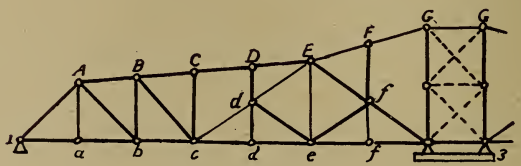


PLATE No. 2 B.

Length, 520 ft. C. to C. of end pins.
Height at centre, 95 ft.
Height at first hips, 50 ft.
Height at end hips, 25 ft.
The chief engineer was J. A. L. Waddell.

We now pass to the next division of the subject, Lift Bridges. Bridges over navigable streams may be divided into four classes, depending on the method used to open the stream for the passage of vessels. These are as follows:

1st, by horizontal translation—the rolling draw,
2nd, by being raised vertically—the direct lift bridge,
3rd, by horizontal rotation—the ordinary swing bridge, and

4th, by vertical rotation or some modification of it—the bascule type of bridge.

We have already touched on class 3; and as bridges in class 1 are now never made at all, we will confine ourselves to classes 2 and 4.

In class 2 there is but one notable bridge, the South Halstead Street Lift Bridge in Chicago. It consists of a single through Pratt truss 130 feet long. The span is so arranged that it may be lifted vertically, high enough to give a head room of 155 feet from mean low water level. As to the success of this bridge I can not do better than quote from **Popular Mechanics:* "The South Halstead Street Lift Bridge was built at a cost of $237,000, and has become famed as a national curiosity. . . There are those in Chicago now who can tell of hours and a night they have spent poised between heaven and earth, on this curious construction; for this bridge, too, developed the faculty of getting out of order, often at the most critical moment. When it would get fastened at the top of the pillars there was no way for the men thereon to get to earth again until they were lowered on the bridge. Food for the people was furnished by means of pails and baskets raised and lowered by means of long ropes." It is quite evident from the foregoing that the bridge could hardly be called a great success. As a piece of structural work, however, it was quite an engineering feat. Its design was by J. A. L. Waddell.

This brings us to class 4, bascule bridges. Apropos of the bascule bridge, we must express our endorsation of Solomon's assertion that "there is no new thing under the sun," for on glancing at the various types that are seen in these modern times, one is struck with the resemblance which some of them bear to the draw-bridges used in the castles and strongholds in the "good old days."

Of the many styles of bascule bridges, those of the trunnion type are perhaps the most widely known, since the newer patterns have not been in use for very long. Probably the most famous bridge of the trunnion type is the Tower Bridge in London, England. It is

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* *Popular Mechanics*, August 16th, 1902.

almost too well known to need any description. Its essential features are two folding leaves swinging on trunnions. To provide for the road traffic when the bridge is open, there is an overhead roadway reached by means of elevators at each end. The bridge has been found to be very expensive in operation.

We will consider very briefly Rolling Lift Bridges, the commonest example of which is the Scherzer. These Scherzer bridges are constructed by the Scherzer Rolling Lift Bridge Co. of Chicago. Instead of having the bridge leaves swing about a trunnion, they roll on the segment of a circle. Each leaf is, of course, counterbalanced, and in the case of a two-leaf structure each shore end engages heavy anchors to resist the bending moment due to live load. As each leaf

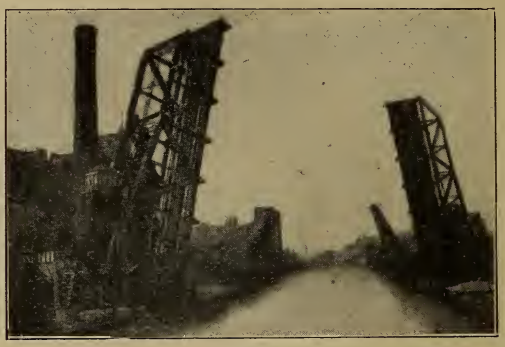


PLATE No. 4.

swings upward, its centre of gravity moves in the arc of a circle, consequently the moment of the weight of the leaf about either its pivot, or its point of rotation, decreases approximately as the cosine of the angle swept out. Because of this, counterbalancing must be of such a nature that the combined C. of G. either remains stationary, or else moves in a horizontal straight line. Various schemes have been tried to accomplish this, nearly all of which have been more or less successful. Among these schemes may be mentioned one or two that have been used in those cases where counterbalances have been attached to cables

which passed over pulleys at the top of the bridge tower. In the first of these, weights are dropped off the counterbalance as the leaf rises. In the second, the track, upon which the counterbalance travels, is curved in a vertical plane, thus rendering its weight less and less effective as the leaf approaches more and more the vertical position. Lack of space prevents more than a brief reference to the bridges of the Scherzer company. They have proved themselves to be very economical in power consumption, and exceedingly reliable wherever they have been placed. Plates Nos. 4 and 5 shew the Scherzer rolling lift bridge at the Grand Central Station at Chicago.

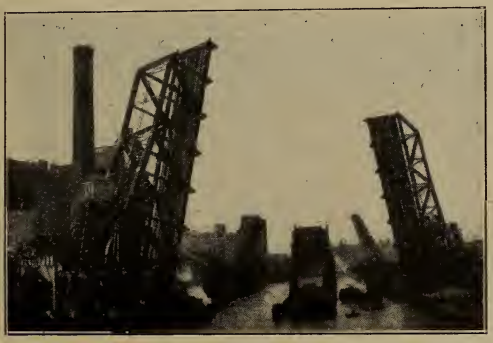


PLATE No. 5.

Another bridge of the rolling type is the John P. Cowing Patent Lift Bridge. It took the highest award for lift bridges at the St. Louis Exposition, and this company is at present building one of their bridges at Jefferson Street, Cleveland, Ohio. Its essential features are shewn in Plate 6.

In conclusion, I would like to make a few comparisons between the centre pier type of movable bridge, and the modern rolling lift type.

I. Time of Opening.—The writer took the time of quite a number of lifts of the Scherzer bridge at Buffalo. In no case did it

exceed nineteen seconds. Compare this time with the one and a half minutes usually required with the other style.

II. Clear Channel.—With the Scherzer bridge no centre pier is required. The whole of the waterway is thus available for vessel traffic. Contrast photos. 4 and 5. Photo. 5 shows the swing pier still present.

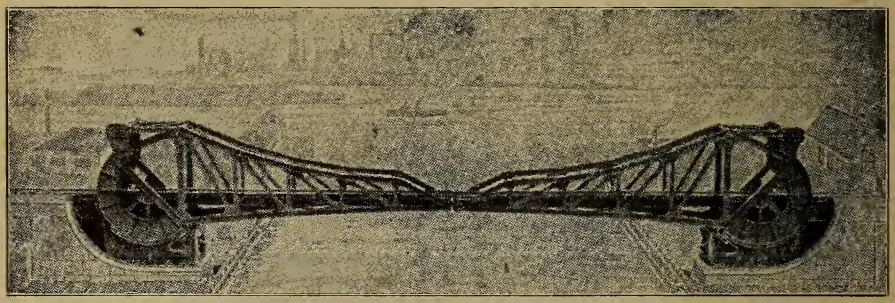


PLATE No. 6.

III. Cheapness of Operation.— The Scherzer bridges are much more cheaply operated than are the others.

IV. Safety.—Since the lifted leaf in the Scherzer bridge completely blocks the roadway, it is impossible for persons or vehicles to fall from the road into the stream.

ELECTRIC STREET RAILWAYS AND THEIR EQUIPMENT.

L. W. Morden, '05.

The first application of electricity as a motive power was made by Thos. Davenport, of Vermont, in 1835. He constructed a car operated by a motor of his own invention, the current for which was derived from voltaic batteries carried on the car.

The idea of taking electric current from conductors laid parallel to the track was not thought of until 1840.

In 1851 an electric locomotive was constructed by Prof. G. C. Page, which, running on a track, developed a speed of 19 miles an hour. This test was made on the Baltimore & Ohio Railroad. In this case the voltaic battery was also the source of power. In fact up to this time, the battery was practically the only source of electrical energy. It was not until the advent of the dynamo-electric generator that the propulsion of cars by electricity became practical. Very little noticeable advance was made in the electric railway problem until 1881. In that year, in Germany, the first commercial street railway was operated. In 1884, the first American public street railway was put in operation at Providence, R.I. Seventeen years ago, less than 100 miles of electric railway was in operation on this continent. To-day there are about 35,000 miles, with about 75,000 cars, which use continuously about one and a half million horse power of electric energy, and earn annually a quarter of a billion dollars.

In a proposed road, the first question is that of location. The important problem in railway location is and always has been the securing of a maximum traffic, with a minimum cost of construction and operation. In the consideration of the question of maximum

traffic, we should bear in mind that in growing towns an electric road carried into desirable building districts will not only build up its own traffic, but will also increase the value of real estate in its vicinity. The configuration of the town also plays an important part, for if it be long and narrow nearly the whole population can be reached by a single line. In all towns of any size, lines connecting the residential and business portions are desirable.

The systems now in use, differing in their method of supply of current, may be classed as follows,—1, overhead trolley system; 2, open conduit; 3, third rail; 4, storage battery. The general construction of the overhead system is so well known that no detailed description need be given here. The positive terminal of the dynamo connects through the switchboard to the overhead trolley wire, while the negative connects to the rail. From the wire, the current is taken by the trolley on the roof of the car, passes through the motors, thence to the iron framework of car and from there to the track, returning through the rail to the station.

The open conduit system has not been very extensively used on account of the high expense of construction compared with that of the overhead trolley system. In places, however, where the city authorities have refused to allow the stringing of trolley wires and feeders above the surface, it has been installed. Two bare conductors are used, and these are held on insulating supports in the upper part of a channel or conduit built in the roadway between the car rails, in the same way as a conduit for a cable road. In the construction used by the Metropolitan Street Railway Co. of New York, the rails are supported on cast-iron yokes in place of the ordinary ties. The conduit extending between these yokes is made of concrete. In this conduit are the two conductor rails which connect through feeders run in underground ducts alongside of the rail. Connection from the car to the conductor rails is made through a slot left between two slot rails. These rails are of course insulated from the conductor rails. To facilitate the installation of new feeders or the repair of old ones, manholes are provided every 400 ft. In the main conduit manholes are put every 200 ft., thus allowing the removal of the

mud which accumulates very rapidly. At the bottom of the manholes is a 6-inch drain pipe connecting to the sewer. The conductor rails are not continuous, but are divided into sections about a mile long, and each section is fed by its own feeder from the power house. There is no electrical connection between these feeders, so that the road is cut up into insulated sections, and trouble on one section is not so likely to interfere with traffic on others. Another advantage of this sectional feeding is that one section may be started up at a time, thus preventing the heavy overload on power house due to the simultaneous efforts of all motormen to start their cars at once. The plow used by the Metropolitan Co. is provided with two iron contact shoes that press sideways against the conductor rails under the action of two flat springs. Electrical connection is made by cables that connect to flat insulated strips passing through the plow, which strips are connected to the shoes by means of flexible cables. The plow is securely fastened to the cross-head underneath the car, and this cross-head is mounted so that it can move from one side of the car to the other in order that the plow can change its position relative to the car when necessary.

The electro-magnetic system has not been adopted very extensively, one of the chief objections arising from the number of automatic switching devices necessary. In this system the regular rails constitute one side of the circuit. The other side consists of an insulated third rail split up into a number of short sections. These rail-sections are supplied with current by successively connecting them to a line conductor run alongside the track, this connection being made by means of electro-magnetic switches. In the switch-box and connected to the switch-lever are two armatures that are alternately attracted by magnets on the car, one in front and the other at the rear end, so that any section has current in it only so long as the car is passing over it. For collecting the current a sliding shoe is used.

The third rail system, instead of being a comparatively new system, is really one of the oldest. Of late years this system is coming much into favour, especially for heavy work, such as there is on

interurban and elevated roads. The third rail is mounted usually on special insulators at one side of the track. Contact is made with this by means of a sliding shoe. This system can of course only be used where there will be no likelihood of persons coming in contact with it, being particularly applicable to elevated roads. On each car are placed two shoes 33 ft. apart, so that at crossings the third rail may be omitted, the momentum acquired by the car being sufficient to carry it across.

The storage battery system is an ideal solution of the problem of electrical transportation, but it has yet to be developed into a perfectly satisfactory system. The reason for this unsatisfactory state of affairs can be found in the batteries themselves. They cannot stand the strain of the heavy work required of them in starting the car. They also deteriorate rapidly. The great weight is also a serious objection.

Electric street cars are operated almost wholly by means of direct current. This means that the current actually supplied to the motors is direct, although the current generated at the power station may be alternating. The reason for this is that the A C motor has not yet proved as reliable for this class of work. It must be remembered, however, that alternating current motors suitable for this work have been making rapid advances, and some roads are at present operated by the alternating current equipment. The general practice so far has been to convert the alternating current into direct current by rotary transformers or motor generator sets at the station, and to use the direct current motors on the cars. This use of alternating current at high pressure as a means of transmitting power has come much into favour because it allows the cars to be operated from a central station situated some distance from the point where the power is used. Could we use a high pressure, a low current would be all that would be necessary, and small feeders would be sufficient; but the pressure at which current is supplied is limited by considerations of safety. The working voltage on street railways has been fixed at about 500 volts. Railway motors and other apparatus are designed for this voltage.

We will now consider somewhat in detail the overhead trolley system. The power house, or power station, should be situated as near as possible to the load centre of the system. In locating this site, future extensions and increase in traffic incidental to the development of outlying districts should be borne in mind. Experience and computation have proved that it is not profitable, with the ordinary direct current 500-volt transmission to operate cars more than 7 miles from the station, because in order to keep the line loss down to a reasonable amount, the feeders must be so large that their cost becomes excessive. Besides the considerations got from looking at the question of situation of station from a purely electrical point of view, there are several others that have a most important bearing on the question. It should be so situated that the coal would not have to be all hauled to it, or at such a place where it would not be difficult to get water for the boilers or condensers. Again, it would not be wise to build a power house in a part of the city where a building would probably pay as good dividends as many well-managed roads. It can be seen then that the final selection of a site for a power house must in some cases be a compromise between conflicting conditions.

The type of engine most suitable for a railway power station depends on the size of the road, i.e., on the number of cars in regular operation. The closest speed regulation under widely varying loads is obtained with high speed automatic cut-off engines, and this class is therefore particularly suitable for very small roads. On most roads, however, it has become the practice to use slow speed engines of Corliss type, especially when the load is moderately large. The station is usually made up of a number of units, each consisting of an engine belted to its dynamo. When the units are very large and also when the space is limited, direct-connected engines and dynamos are to be preferred. In some of the largest stations vertical Corliss engines are used, and these are generally of the compound or triple expansion type. Engines used for the running of street railways should have very heavy fly-wheels, in fact the whole engine construction must be of a very substantial character, because it must be remembered that the load is more subject to severe fluctuations than with electric lighting or ordinary power transmission. The units should be arranged

so that they may be kept loaded up to nearly their capacity and thus not operate at a low efficiency. The engines should, when possible, be run in connection with condensers. The boilers used in railway work are generally of the return tubular or water-tube type. The former is low in first cost and easy to keep in repair; the latter, however, is very largely used because of its safety and because it can make steam very rapidly if the occasion demands it. When space is scarce, vertical boilers may be used to advantage. The electrical equipment may be conveniently divided into two parts: the part that generates the power and the part that is used to control its distribution to the point where it is used. The first part includes the generator and the second the switch-board with all its controlling and measuring devices. The dynamos used for railway work should be exceptionally well built, so as to withstand the sudden strains thrown on them, and should be capable of handling a considerable overload for a short period without excessive sparking or heating. When the power must be carried for long distances, the best plan is to install high pressure alternating current generators to supply current to sub-stations located at various points on the system. Here the voltage is lowered by passing it through transformers, and then changed into direct current by passing through rotary convertors or motor generator sets. In the majority of cases, however, direct current generators are used, and these supply current at pressure of from 500 to 600 volts directly to feeding system. In the early days of electric railroading, shunt dynamos were used, but they have since been displaced by the compound wound machines. Two reasons might be given for the use of the latter. If properly installed they will operate well in parallel, and in the second place, they have the valuable property of holding the voltage constant, or even increasing it as the load is applied. Nearly all railroad generators are over-compounded, i.e., the voltage rises as the load increases, this increase at the machine terminals being usually from about 10 to 20 per cent. In spite of the fact that a railway system may be supplied by a good machine heavily over-compounded, it is quite common to see the voltage on removed parts of the system vary between wide limits. In some cases the lights

almost go out every time the car is started or the speed of a car increased. That such a state of affairs exists is in no way due to a fault in the dynamo. If the dynamo is compounded to look after a 10 to 20 per cent. loss in the line, it can not be expected to look after a 40 to 50 per cent. loss due to a poor rail return circuit, nor can it be expected to compound at some point 4 or 5 miles farther out on the line than it was originally adjusted for.

Many large systems are now installing high pressure revolving field alternators at their main power station and transmitting the alternating current, which is usually two or three phase, the latter being the more common, to sub-stations, where it is changed to direct to be supplied to the cars. The operation of car motors by alternating current has come much into favour during the last year or so, but as yet very few street railway companies have approved of it.

Lack of space will not permit of the consideration that should be given to railway switchboards and their various accessories. These will include devices for controlling and measuring the load, for centralizing the many circuits used, and for the protection of life and property, such as lightning arresters and circuit breakers.

Some roads have one or more feeders that have to run to points some distance farther from the station than others, in which case there will be considerably more drop. Consequently it is necessary to supply these feeders with a higher voltage. For this a number of different schemes are use. One of these is the use of an auxiliary bus bar, to which is connected a machine that generates at a higher voltage than the others. Where a separate machine would not be available, a "booster" may be used. This term "booster," used in railway work for several different appliances, here means a machine used to increase the voltage of the outgoing feeders. This booster, a special dynamo, is placed in series in the feeder. The storage batteries are very valuable as an auxiliary. They may be placed at the end of a long line to keep up the voltage. In power plants or substations that may also be used to steady the load carried by the dynamos or convertors, taking the peak of the load owing to their valuable

property of being able to deliver heavy currents for short intervals. To operate this way the storage battery as a whole is put in multiple with the dynamos, being connected to the same bus bars. During the hours when the load is light, the dynamos not only supply the outside load, but they charge the battery as well, and when the rush hours some on the battery helps the dynamos on the outside load. In stations where the battery is used, the generators are heavily overcompounded, and their terminal voltage therefore varies according to the load. Now, since the E. M. F. of the generators increases as the load increases, and since the E. M. F. of the battery decreases as the load increases, on account of its internal resistance, there must be some means provided for regulating the voltage of the battery to suit that of the bus bars. This regulation is effected by means of a motor-driven booster connected in series with the battery. This booster is designed to increase the effective voltage of the battery at the same rate that the load increases, thus keeping the relationship between its E. M. F. and that of the generator constant. The + ve end of the battery is connected to the + ve bus bar of the station. The — ve end of the battery goes to one terminal of the booster armature, the other end of which goes to ground. The motor end of the booster is run from the station bus bars. Now, as this booster both regulates the voltage at which the battery discharges, and also helps to charge the battery, it must have a provision for not only varying the voltage from zero to a maximum, but for reversing its polarity. This is done by means of a three-point switch. This plan is used by the Buffalo Street Ry. Co., and also by the Hamilton Cataract Power, Light & Traction Co., at Hamilton, Ont. The South Side Elevated Road of Chicago uses the storage batteries out on the line. They are connected directly across the line, without any booster, depending for automatic regulation on the variations in the drop (from 10 to 30 volts), which takes place between them and the power house. When the load is light, the drop is small, and the voltage of the feeder being above that of the battery, sends a charging current through it. When the load is heavy, the excessive drop brings the feeder voltage down below that of the battery, enabling the latter to send a current out on

the line, thereby aiding the power house. In order to make sure of the necessary variation in drop, the battery is connected to the power house through two special feeders, by means of which the required regulation can be got. A drop of 10 per cent. in the line is sufficient to allow the battery to operate automatically as described.

In the consideration of the amount of power necessary for operation, several factors necessarily come in—weight of equipment, number and speed of cars, kind of traffic, manner of handling equipment, condition of line and rail return, and the topography of the road (grades, curves, etc.). From several observations made on standard equipments for weight of cars, the following approximate values were taken:—

Open Car:

(a) Body (without equipment except light wiring), 320 lbs. per linear ft.

(b) Car properly equipped, 650 lbs. per linear ft.

Closed Car:

(a) Body (without equipment except light wiring), 395 lbs. per ft.

(b) Car properly equipped, 880 lbs. per ft.

Note—For open car measurement was made over all; for closed car, measurement was made between outsides of bulkheads.

Equipment Complete:

Motors, trucks, brake rigging, etc., about 300 lbs. per H. P.

It has been determined experimentally that .06 H. P. applied to the wheels of a car will impel one ton on a level track at the rate of one mile per hour. An efficiency of about 70 per cent. must be allowed for between rail and trolley wire. The amount of current required to run a car is proportional to its weight, and almost proportional to its speed up to 12 miles per hour. The following table may

be useful in showing the amount of power necessary to drive a loaded 16 ft. car at various speeds and on various grades:—

Grade Per Cent.	Miles Per Hour.									
	2	4	6	8	10	15	20	25	30	40
0.	.7	1.3	2.1	2.8	3.6	5.7	8.4	12.1	16.5	28.9
1.	1.6	3.1	4.7	6.4	8.0	12.4	17.4	23.3	30.0	46.8
2.	2.5	4.9	7.4	9.9	12.5	19.1	26.3	34.4	43.3	64.6
3.	3.4	6.7	10.0	13.5	17.0	25.9	35.2	46.6	56.7	82.5
4.	4.2	8.5	12.7	17 1	21.4	32.5	44.1	56.8	70.1	..
5.	5.1	10.3	15.4	20.6	25.9	39.2	53.1	67.9	..	..
6.	6.0	12.1	18.1	24.2	30.4	45.9	62.0	75.1	..	..
7.	6.9	13.8	20.8	27.8	34.8	52.6	70.9	..	..	..
8.	7.8	15.6	23.4	31.4	39.3	59.3	79.9	..	..	..
9.	8.7	17.4	26.1	34.9	43.8	66.0	..	..	..	..
10.	9.6	19.2	28.8	38.5	48.2	72.7	..	..	..	..

From this table it will be seen that the power taken by a car is almost directly proportional to the steepness of the grade that it is ascending. This relationship does not hold so well for the lower grades. The draw-bar pull per ton weight required to move a trolley car on a level track at uniform speed is somewhat higher than that on steam roads, usually taking about 25 lbs. per ton to keep the car moving uniformly. The amount of power required for motors necessary to move a car may also be determined approximately from the following formula:

$$\text{H. P.} = \frac{h\,W + D\,f}{33000\,E} \quad \text{where}$$

H. P. = total horse power required for motor,

W = weight of car in pounds,

E = motor efficiency in per cent.,

h = perpendicular distance in feet ascended in 1 minute,

D = horizontal distance in feet travelled in 1 minute,

f = force in pounds necessary to move car.

The power required in going around curves depends on their radius and on the construction of the track. The power required

for rounding curves may be taken approximately to be the same as that for starting up. Experimentally it has been found that a force of about 70 lbs. per ton weight is required to start a car or keep it in motion while rounding curves. When starting on a grade, the effort must be greater in proportion to the percentage of rise, and for this condition add 20 lbs. to the 70 lbs. for every ton weight for each 1 per cent. of grade. On a level track the maximum force that could be applied without slipping resulting would be about 1-8 of the weight of the car. This amount would of course be much less for muddy or greasy rails, while clean dry rails might increase this amount considerably. From the foregoing data safe values for the amount of power used by a single car can not be obtained, but for a given number of cars will hold approximately true.

The cost of generating power in electric railway plants varies greatly, as one would naturally expect, and consequently only approximate figures can be given. The accompanying table, taken from the Street Railway Review, gives figures relating to the cost of generating power in some stations of considerable size. (No allowance is made for investment or depreciation of plant). See table, p. 106.

In a large number of plants the total cost, including interest, etc., will be between 1 and 2 cents per kilowatt-hour, and in some of the larger plants it may be somewhat below 1 cent. The amount of power required to operate each car also varies greatly on different roads, and the cost per car mile is consequently subject to wide fluctuations. The total operating expenses per car mile, including repairs of all kinds, office expenses, cost of labour, etc., is between 10 and 15 cents on a number of roads. The following shows the power consumption for a road operating about 400 cars, most of which are large double truck cars, which consequently take a comparatively large current.

Average amperes used per car, 75.

Voltage, 500.

Cost of power per K.W. hour at power house, 2c.

Cost of power per hour per car, 75c.

Station.	Month.	Monthly Output. Kilowatt-hours.	Cost of electrical output per Kilowatt—Hour—Cents.						Gals. Cylinder Oil per 10,000 K. W. H.	Gals. Lubricating Oil per 10,000 K. W. H.	Lbs. Water per Lb. Coal.	Lbs. Fuel per K. W. H.	Price of Fuel per Ton of 2,000 lbs.	Kind of Fuel.
			Fuel.	Labour.	Supplies, oil, waste, etc.	Water.	Repairs.	Total.						
1	January.	2455060	.322	.111	.029	.029	.044	.535	2.62	.848	10.83	2.45	$2.63	Bituminous.
1	February.	2511280	.334	.114	.036	.027	.025	.536	2.64	.829	10.05	2.54	2.63	"
1	March.	2097160	.337	.123	.037	.030	.040	.567	2.84	.987	11.21	2.55	2.64	"
1	April.	2158660	.344	.129	.039	.032	.043	.587	2.98	.722	11.37	2.61	2.64	"
5	January.	2445161	.408	.110	.013	.011	.016	.558	2.18	1.31	5.51	4.10	1.99	"
5	February.	2512125	.389	.116	.014	.008	.011	.538	2.50	1.08	5.32	3.89	2.00	"
5	March.	2352698	.405	.126	.018	.011	.016	.576	2.52	1.70	5.15	4.33	1.87	"
5	April.	1887029	.347	.149	.020	.011	.036	.563	3.91	1.14	5.22	4.22	1.65	"
6	November	827008	.712	.198	.033	....	.067	1.010	....	....	....	2.35	.943*	Oil.
6	December	810728	.709	.198	.024	....	.070	1.001	....	....	....	2.36	.937*	"
6	January.	643482	.680	.251	.038	....	.185	1.154	....	....	....	2.24	.945*	"
6	February.	494000	.655	.282	.037	....	.181	1.155	....	....	....	2.25	.905*	"
6	March.	562574	.761	.266	.031	....	.059	1.117	....	....	....	2.42	.976*	"
6	April.	616634	.628	.236	.030	....	.095	.989	....	....	....	2.31	.843*	"

*Price of oil per barrel. Output measured by Wattmeter in each case.

The term line, which with a street railway covers a large field of work, will be considered here as referring to the conducting system of the overhead trolley road, i.e., the overhead line construction and rail return. The overhead construction, which includes the setting of poles, stringing of feed, trolley, span, guard, and anchor wires, insulating hangers, switches, etc., is a much cheaper construction than any of the others. Before calculations as to line resistance can be made the following conditions must be known:—

1. The voltage at station; 2, the amount of current necessary; 3, allowable amount of "line drop"; 4, average distance of load transmission.

Street railway generators are now almost altogether built to generate at 500 volts, which voltage may be considered as a compromise between the considerations of economy in copper on the one hand, and the safety to life and facility of insulation on the other. The question of the amount of current necessary has already been discussed. The allowable "drop" is determined principally by the requirement of a close uniformity of condition, in order that the same motors moving all along the line shall be able to give uniform results at all places. It has been found that a variation of from 10 to 15 per cent. in voltage from the highest to the lowest points will not seriously affect the speed demanded of the motors. On any section the average pressure should not be less than 450 volts, and the minimum not less than 400 volts, the average minimum pressures being found under conditions of maximum load for regular traffic. The question of distance of load transmission and the necessary distribution of copper is a most important one. Many different methods are used in practice, depending usually on the local conditions. For small roads, where only a few cars are operated, a single trolley line, No. 0 or No. 00, B. & S. wire, will be sufficient. Of course the farther from the power house the lower will be the voltage. This condition will be considerably improved by running a feeder out from the power house into which taps are made from the trolley at intervals of from 500 to 1,000 ft. In this case a smaller trolley would suffice, No. 6 to No. 0, B. & S. wire, might be used. In larger systems, there

would be with this system considerable drop in the parts remote from the power house. A more equal distribution of pressure may be got by running several independent feeders direct from the power house to different points on the system. The sections fed by these feeders may be electrically connected together or not as it is desired. Each of these sections is equipped with cut-out switches, thus permitting of the localization of trouble. One disadvantage of this is that the cars at one side of a break in trolley are deprived of power. It is often advisable to run more than one feeder to a section, thus keeping down the size of the trolley wire. The total additional cost of the feeder over the bare wire, including the cost of placing the feeder in position and connecting it to the trolley, may be roughly estimated at $100 per mile, the cost of the insulation being figured at 7 cents per lb. of copper.

There are in general use three styles of support for trolley wires. They may be suspended directly from brackets on poles at the side of the road; or a double track may be provided with centre poles carrying the wire on a projecting arm on either side; or the poles may be placed at the sides of the street and the trolley wire supported by span wires stretched across. This latter method is the most common, it being preferred because it does not obstruct the centre of the roadway, and when single track is laid with the prospect in view of making it a double track, the side-pole span wire construction leaves very little additional work to be done when the track is doubled. In many cases on single track two trolley wires are strung alonside of each other about 8 in. apart, one wire used going one way and the other coming back, thus saving overhead special work at turn-outs. In this case all that is necessary to double track is to slide one wire over into place.

A method of suspension that is coming much into favour to-day for high tension high speed railway transmission is known as the Catenary Suspension. The method of support is by a steel messenger cable connected to the trolley wire by vertical steel rods of such a length that the trolley remains horizontal while the steel wire hangs in a catenary curve hung between poles that may be placed

as far as 250 feet apart. A modification of this is known as the Double Catenary, in which two steel cables are strung instead of one.

Centre pole construction can be used to good advantage on very wide streets. When the side bracket construction is used, the track is generally on one side of the street. It is used most extensively for cross-country lines, where a single track runs alongside of the road. For this class of the work cheap gas pipe brackets are generally used. At the present time the poles used are either steel or wood. For ordinary use the diameter of the base of a wooden pole should not be less than 10 in., tapering to 6 or 7 in. at the top, which should be cut in a conical shape so as to shed water. The part that is underground should have applied to it a preservative of some sort such as tar. To offset the tendency of the span wires to pull the tops of the poles together, the poles are all canted outwards about 6 in. or more out of plumb. Great care should be taken in the setting of poles, for if improperly set they will give rise to most serious trouble. The outward slant of a steel pole should be about half that of a wooden one in the same soil. Steel poles are usually set in concrete. The poles are placed not more than 125 ft. apart, and between opposite poles are stretched the span wires, so that they will allow the trolley to hang about 19 ft. above the rail. At intervals of about 500 ft. and at approach of all curves anchor wires are put up to hold the wire in position in the direction of its length. In going around a curve the trolley wire does not follow the centre line between the rails, but is strung over toward the inside rail. This offset depends on the radius of curve, which offset measured at the middle of a 90° curve should be about as follows:—

Rad. of curve in feet.	Offset ins.
40	16
60	12
80	8
100	6
150	4
200	3

The object of this is to allow the trolley wheel to lie more closely to the wire. When there is danger of telephone or other wires falling

across the trolley wire, guard wires are strung across. A description is omitted here of the necessary equipment for the support and insulation of wires, such as hangers, insulators, clinch ears, pull-overs, switch pans, cross-overs and line breakers. They are all of simple construction, and descriptions can be obtained from almost any catalogue.

The calculation for feeders for an electric railway involves a great deal of careful study of the particular conditions, and it is impossible to lay down any general laws to govern all cases. While this question is one of very great importance, the lack of space will not permit of its discussion. The following formula for rough approximate feeder calculations under average conditions may be given, however:—

$$\text{No of circular mils} = \frac{10.8 \times l \times c}{e} \quad \text{where } e = \text{volts drop:}$$

c = No. of amp's flowing through it.

l = length in feet of copper part of circuit.

This formula does not take into consideration the resistance of the rail return circuit. In order to take this into account it will be necessary to change the constant 10.8 to 14.4. The whole matter really consists of an application of Ohm's law, sometimes rather complicated.

Some roads, principally conduit or slot roads, do not use a rail return, but copper conductors instead. This metallic return has the advantage of taking two grounds to tie up a road, and these grounds must be on opposite sides of the system. In the rail return, it is desirable to avoid setting up a high current density in the earth at points along the line, causing localized earth currents to be set up that will seriously interfere with the underground circuits or even produce considerable electric effect on metallic pipes or cables, known as electrolysis. While the current ordinarily is supposed to return by way of the rail, it often happens that there is an iron or lead pipe in close proximity to the rail, and much of the current will leave the rails and return by this pipe. An electrolytic action is set up where this current leaves the pipe, and in course of time will eat

holes in the pipe. One ampere flowing steadily for one year will eat away about 20 lbs. of iron or 75 lbs. of lead. This corrosion not only occurs near the power house, but at points where the current would leave one pipe for another of better conductivity, say from an iron to a lead, or even return to the rail again. By taking the voltage between the pipe and the rail at different places on the system the points where the pipe is + ve to the rail are found, and these dangerous points may be connected directly to return feeders and thus prevent damage resulting from this current going from the pipes into the ground. All the ground pipes in the immediate vicinity of the power station should be connected electrically to the — ve side of the generator. Ground plates placed below the level of the pipes in moist earth are a considerable aid to conductivity, and prevent the formation of high local current densities in the earth. One of the most effective means of preventing electrolysis is to see that the rails are thoroughly bonded, so that the rail will have a good conductivity and leave no inducement for the current to leave it. There is hardly any feature of electric railway construction that demands more care and attention than the rail joints. To get a joint that is mechanically good is a comparatively easy matter, but it is a far harder matter to get one that is electrically good, and a still harder matter to keep it in that condition. A bad joint may have more resistance than several hundred feet of rail itself, in fact it may even refuse to allow of the passing of current at all. The ends of abutting rails are connected electrically by means of bond wires. These bonds are designed to give the best possible contact between rail and bond, and to withstand the tendency to break off under the action of the continuous vibration and pounding to which they are subjected. A description of the great number of different types in use is out of the question here. These bonds are sometimes placed underneath the fish-plate. Two of them may be used, connecting each end of the fish-plate to the rail. In the calculations of resistance of bonds we may assume them to have that of one foot of No. 0000 wire. In order to prevent the break in circuit subject to the breaking of a bond, it is good practice to connect over to the other rail at short intervals along the line. On some roads an extra

ground feeder is run along the track, into which taps are run from the rail at regular intervals. Some roads have welded their rails together either by heating with electricity or by surrounding the joint with a mould, into which is poured cast iron. While this plan has met with considerable favour, several authorities do not approve of it, preferring the regular fish-plate joint.

The permanent character of the track as a whole depends greatly on the character of the roadbed. During the last half century steam railway engineers have studied track construction, and no better practice for street railway men can be followed than that now adopted by these. The conditions of pavement and wagon traffic make the street railway problem more difficult, but considering the question from the railway company's standpoint for its own traffic the T-rail construction as used on the steam road is the best. The girder rail, the use of which is demanded by most city corporations, prevents the wearing of the pavement alongside of it, and is more conducive to good wagon traffic. The question of the placing of rails is still an open one, some authorities being in favour of staggering the joints, while others prefer to put them opposite each other. The former plan is perhaps the one in most general use. Guard rails with the protecting flange prevent a car from climbing the rail on a curve. They are placed usually on the inside of the curve, but sometimes on both sides. It will not be possible to here give a treatise on track construction.

For calculations for the resistance of rails we may assume their composition, mild steel, to have a resistance of seven times that of copper. The following formula may be used for the calculation of rail resistance: $r = \frac{.00178}{w}$ where r = resistance in ohms of 1 yard of mild steel, and w = weight in pounds per yard.

The resistance of 1,000 feet of single rail (not including joints) is equal to .6 divided by the weight in pounds per yard. These formulæ would hold in the case of the electrically welded rail, in which case there is really no joint. In the case of the ordinary

bonded rail joint these values are materially increased, the resistance of the bond itself being considered that of one foot of No. 0000 copper, which is .00005 ohms. The bond contact resistance will vary considerably from .000005 to .0008 ohms. Some of the best authorities on this matter give .0002 ohms as a safe value for calculations. The resistance of 1,000 feet of single track has been given as .0111 ohms (calculated for a 30 ft. 80 lb. rail).

Under the head of auxiliary equipment will be included car houses, car barns, repair shops, etc. It is the custom on large roads to have one large well-appointed repair shop as centrally located as possible in reference to the several depots or car houses where the cars are stored, and from which they are sent out on their runs. These car houses should be fitted up to allow of light repairs, and from a storage standpoint should be as nearly fire proof as possible. Car houses may have one or more floors, depending on the particular use they are to be put to. It is not good practice to use anything but the ground floor for the storing of cars in everyday use. It is a good plan to keep stored cars on trucks, which may be of a light temporary order. When practicable, every storage track should lead to the street at one end or the other. In some houses it is the practice to grade the rails down to the street, so that to move them, it is only necessary to release the brakes. Provision should be made for the draining of the water used in the washing of the cars. For the inspection of trucks and motors there should be pits about 4 ft. 8 in. deep directly under the tracks. It is a difficult matter to fix the amount of pit room per car, but for large houses, experience has proved that about one linear foot of pit room for each car going into it will meet the requirements. This does not hold so well for smaller houses. In no case, however, should the pit be shorter than the car that is to be placed over it. It should have cement floors and be properly drained. Each pit should be provided with a pit jack for the removal of armatures. A well-equipped repair shop should include pit room, machine shop, carpenter shop, blacksmith shop, paint shop, winding room, commutator room and controller room. All that was said of the pits for the car houses is applicable to the repair shop.

There should also be means provided for raising car bodies from the trucks conveniently.

The machine shop for a railway repair shop should, as should be the case in all good machine shops, be laid out to get the best light and to use as little floor space as possible. To properly equip it the following machines are necessary: three lathes, one large enough to take an axle with wheels on it, one small one to take armatures and bearings, and a speed lathe; a large and a small drill press; one planer and shaper; one bolt cutting machine; emery wheels; grindstone; ratchet drill, and punch press. A hydraulic press is also a valuable acquisition in a repair shop.

The winding room, if the space on the ground floor is limited, may be very well situated over the machine shop. If so placed, means must be provided for elevating to it cores and armatures for repairs and re-winding. To do all its own work, it should be equipped with all the apparatus necessary for the formation and insulating of the armature and field coils. This would include a machine for putting on armature bands, a field winding machine (a lathe will answer for these last two), and stands for holding armatures in the course of construction.

While it is desirable to have commutator and controller rooms, they are not absolutely necessary, as the work usually done in them can be done in machine shop and winding rooms. For this work, a lathe, drill press, milling machine, and baking oven are necessary, also a full line of gauges. No detail of the equipment of the carpenter, paint, and blacksmith shops is necessary, except perhaps to say that the latter should be situated where the coal dust and gases from the forge cannot reach the paint shop.

The term rolling stock in electric railway work is applied to the car bodies and trucks, including sweepers and snow plows. Under this head may also be included the electrical and brake equipment. Only a brief discussion on the different parts is all that may be allowed here. The car body constitutes the main part of the car, and is mounted on either a single truck or on two trucks, depending on its length. Lengths vary from 18 or 20 ft. to 40 or 50 ft. The

single truck car is fast giving way to the double truck, as it has been found that in most cases it pays better to run long cars at long but certain intervals than at shorter intervals. The double truck is easier on the car body, on the line, on the track, and further is more comfortable and more attractive. The double truck closed car takes longer to unload, and is therefore not as well adapted for short local runs as for long runs, where the stops are not so frequent. The use of trailers is not as general as formerly. While they are a saving in power, they are very awkward, making the combination not so easy to handle, thus causing a loss of time and increasing the liability to accidents. The main requirements of a good truck are that it be easy riding, that it have few parts, that the wearing parts can be easily replaced and wheels easily changed. The term "truck" applies not only to the mere framework, but also to the wheels, axles, brakes, motors, and driving gears. A car body should have a double truck if the wheel base, i.e., the distance between the wheel centres measured along the rail, is over 7 ft.

The first method used to control the speed of the motors was to mount a rheostat underneath the car, and by means of a controlling device at either end of the car this was cut in or out. This method, known as the rheostatic method, can be used with one or more motors, but it is very little used, being very wasteful of power, especially at the lower speeds. This old style of rheostat with its movable arm was soon replaced by the platform controller. From the resistance box under the car and the motors, wires were run to a controller placed on the platform. The controller is a device for cutting out the resistance or for effecting any combinations necessary for the control of the speed. Many kinds of controllers are made to meet the different conditions of service. In the General Electric controller a magnetic field is used to extinguish the arc that would otherwise form at the contact tips and cause blistering and burning. Type R of their make uses its own rheostatic control. The controller is furnished with a reversing switch, and to prevent the movement of this when the current is on, there is also provided an interlocking device. If the motors were reversed with the power on the back E. M. F., instead of opposing the line E. M. F., would be added to it,

and a very large current would be forced through the motors, and besides there would be no resistance in series with the motors. The result would be much the same as would happen with a very bad short circuit, and the main fuse would be blown. In some controllers this reversal is brought about by reversing the direction of the current through the armature, as in the G. E. controllers, while this is done by reversing the current through the field in the Westinghouse.

The method of speed control now almost universally used for street railway work is known as the series parallel method. This method enables the voltage applied to the motors to be cut down for slow speed running without the use of resistance, and is hence more economical for low speed than the rheostatic method. At least two motors per car are required. For slow speed the motors are connected in series, and for high speed are connected in parallel; that is, the motors designed for 500 volts each, have at first, when in series, 500 volts across both, or 250 volts across each, and each motor will then have to run at about half its normal speed to generate the required back E. M. F. For the higher speeds the motors, when thrown in parallel, have their full 500 volts across each. In order to prevent the heavy rushes of current that would be got at starting, resistances are cut in, and also when changing from series to parallel. These resistance notches must of course not be used as running notches. Controllers are all equipped with cut-out switches, by means of which one of the motors may be cut out in case of trouble. With a 4-motor equipment the motors are connected in pairs in parallel and the two pairs are treated as if they were single motors, and are operated by the series-parallel method just described.

Street railway motors have to meet several conditions not imposed on motors that are used for stationary work. Its design is limited to a large extent by the space in which it is to be placed. It must go wholly beneath the car floor, and its width is limited by the gauge of the track. It must be arranged so that it can be readily suspended from the car axle, and as it has to run in all kinds of weather, must be dust and water proof. No other kind of motor

is subjected to harder usage than that given to the street railway motor, and it must therefore be of a most substantial character. The general construction is much the same as any other motor. The field frame of a direct current motor is made so that it will enclose the motor as much as possible. Formerly motors were only partially enclosed, but now all are wholly enclosed. They are now nearly all of the 4-pole type with cast steel magnet frame, which permits of a lighter and stronger construction. It has not been found practical or economical to drive ordinary street cars by means of direct connected motors, i.e., by means of motors the armatures of which drive the axle directly without the use of gearing, except where the motors are very large. This is the case with electric locomotives. If the motor drives the axle directly, the speed of the armature must of course be the same as that of the axle. This means that the motors must be designed for a very low speed, and therefore heavy and bulky for their output. To get over this difficulty, the practice is now to use geared motors, so that the armature may be allowed to revolve four or five times as fast as the axle. Railway motors have to run in either direction and are subjected to great variations in load. It is therefore impossible to equip them with any brush shifting arrangement, the brushes being fixed permanently at the neutral point. A railway armature which is now almost always drum wound is connected so that even if it have four poles, there will be but two paths through it, and all that will then be necessary is two brush holders, which are set on the upper part of the commutator and thus easy of access.

One of the most important items in the equipment of a car is the brake. Most of the cars in common use are equipped with hand brakes. Air brakes are coming much into favour, especially for the control of the heavier cars. Electric brakes are also very generally used. Before giving a brief description of the operation of each of these we will consider the question of shoe pressure. The amount of pressure required to brake a car depends on the speed and weight, and also on the number of wheels that have shoes applied to them, thus making it a question of friction between wheel and shoe. It has been found experimentally that the friction between the wheel

and shoe amounts to from 15 to 30 per cent. of the applied pressure. On a slippery rail, where one would be liable to apply too much brake pressure, it is advisable to apply sand, thus increasing the friction between the wheel and rail.

With the hand brake the shoes are forced against the wheels by a system of levers operated by a handle, under the control of the motorman.

Air brakes as used on electric cars may be divided into two classes, known as straight air and automatic air. In both cases the brakes are set by allowing the compressed air, stored in a reservoir, to expand into a brake cylinder, thus moving the piston and operating the brake levers. In the automatic air equipment the air passes through an automatic valve device in going from the reservoir into the brake cylinder, instead of going direct, as is the case with the straight air equipment. The main valves which cause the application or release of the brakes are operated by a single lever by the motorman. The straight air equipment is simpler and safer than the automatic air, and consequently more generally used on the ordinary street car, but where the brakes are used on long trains of cars and it is necessary to apply all the brakes at once, the automatic air equipment is used, as it permits of this. For the straight air equipment the principal parts are a compressor hung under the side of the car; a small geared motor for driving the compressor; an automatic governor for the control of the motor, starting and stopping it when the desired pressure is obtained, about 60 lbs. per sq. in.; a reservoir for storing the air from the compressor; the brake cylinder and the necessary valves, including the brake or engineer's valve. For the automatic air equipment the main reservoir and compressor are on the engine or motor car, each of the other cars having a brake cylinder, an auxiliary reservoir, and an automatic triple valve, which is controlled through a connecting pipe to the main reservoir by the motorman. On some roads using the air brakes, instead of having the compressor on the car, they have a compressing station on the line from which the reservoirs on the car are charged. This, of course, has to be done frequently, but as the operation is only a

short one, the cars are not very much delayed. Electric brakes have been made by both the General Electric Company and Westinghouse Company, both of which make the motors act as generators to supply the necessary current, thus not requiring any additional current from the station.

It is only in the last few years that a satisfactory running contact in connection with trolley apparatus has been obtained. A brass grooved wheel about 5 in. in diameter, centred on rawhide or graphite journals, and held in a fork or harp of brass, or better, malleable iron, is mounted at the end of a steel pole from 12 to 15 feet long, tapered from $1\frac{1}{2}$ to 1 inch in diameter. This pole trails back from the middle of the car roof at an angle of about 30 or 40° from the vertical when the trolley wire is 18 feet above the rail. It is set in a socket attached to a framework, "the trolley base," on the car roof. The trolley stand is equipped with spring devices that permit of an up and down motion, allowing the pole to adjust itself to the different heights of wire. It also permits of a side motion, so that it can follow the wire freely in going around curves. The pressure with which the wheel acts against the trolley wire varies from 10 to 20 pounds, according to local conditions, about 15 pounds giving perhaps the best results. From the trolley base the main wiring of the car runs to the hood or canopy switch placed in the motorman's box. By means of this switch all further electrical connection to the car is cut off. As this switch sometimes is called upon to break currents from 100 to 250 amperes, special provision is necessary to prevent too much arcing. The General Electric switch is provided with a magnetic blow-out to extinguish the arc. The Westinghouse Company accomplish this by having the switch blade break the current in two different places at once. From the canopy or hood switch the main circuit runs to a fuse box, which affords a further protection, acting automatically. The hood switch and fuse box have lately in many cases been replaced by a circuit breaker, which answers the purpose of both of them. From the fuse box the wires run to the two controllers.

Cars should be provided with lightning arresters, which are usually connected directly between the trolley and the ground. The

arrester made by the Westinghouse Company extinguishes the arc that would follow the discharge by confining it between two *lignum vitae* blocks, where it is smothered out. Those made by the General Electric are of the magnetic blow-out type. Besides the main circuit handling the current for the actual propulsion of the car, we have other independent ones, for the lighting and in some cases the heating of the car. The use of electricity for heating is extensively used, although in most cases slightly more expensive to operate than a stove. Where the cold is not excessive, to keep a car comfortable it would require about 10 amperes at 500 volts, i.e., between 6 and 7 horse power. On the other hand the electric heater is much cleaner, more easily regulated, distributes the heat more uniformly, and takes no valuable room, being usually placed under the car seats.

The lighting circuits, one or more in parallel, usually have five lamps in series, thus obtaining the necessary 100 volts across each and the 500 between trolley and ground. The lighting circuit affords a ready means of telling whether the power is on or off, and consequently to be relied upon, should always be kept in the best of condition. Lamp circuits should always be tested before dark.

COBALT MINES.

W. J. Blair, B.A. Sc.

A year ago, little could have been written or said of the mines at Cobalt. To a few men on the ground there came but a faint glimmer of the richness of the deposits. The general public had not even heard of Cobalt, and those who had heard disbelieved the reports.

The town of Cobalt is situated in the Township of Coleman, about five miles from Lake Temiscaming. It is on the new Government railway, The Temiscaming and Northern Ontario, one hundred and three miles from North Bay and nearly straight north from Toronto three hundred and thirty miles. These rare deposits of valuable mineral lay from decade to decade within a very short distance of this large lake, so well known to the earliest voyageurs and frontier missionaries. They are within four miles of a wagon road used for a quarter of a century by the Hudson's Bay Company, between the Montreal River and Lake Temiscaming. It is twenty years since the meridian which forms the east boundary of the Township of Coleman was run by O. L. S. Niven, and nearly as long since C. D. Bowman, O.L.S., sub-divided the Township of Bucke, which adjoins Coleman on the north. Both these surveys were within a mile of Cobalt. For many years lumbering operations were carried on right on top of these deposits. In fact camps were built within a stone's throw of a spot where over $1,000 worth of nuggets of native silver were picked off the surface. But it was left until July, 1903, for the first real discovery of mineral in the Cobalt district to be made.

It was made by two men connected with the construction of the Temiscaming Railway, the spot afterwards becoming "The McKinley-Darragh Mine," after the discoverers. This claim was not surveyed nor recorded at the time. Other discoveries made during the same year were the La Rose vein, the Little Silver vein, and the large vein on Cobalt Hill. No development work was attempted during 1903. An examination of the deposits and the immediate vicinity was, however, made under the direction of the Bureau of Mines, and this examination shewed that they were extremely rich. As a consequence a careful geological survey of the district was begun in the spring of 1904, and instructions issued for the survey of Coleman Township.

With the opening of spring, a half dozen or so prospectors were attracted to the locality and two important discoveries were made in the month of May. These are on Mining Location J. B. 6, and J. B. 7, and are what are now known as the Trethewey Mine. No other discoveries are noted until July of the same year, when we have those in the immediate locality of Cross Lake. A few weeks later the first discoveries were made in what is now known as the Kerr and Giroux Lake belt. This brings us to October, 1904.

Up to this time, no development had been done except on those discoveries mentioned as having been made in 1903, and on the vein on J. B. 7. The steel on the Temiscaming Railway did not reach Cobalt until late in October, and it was some time after this before the first car of ore was sent to the sampler. The winter of 1904-05 saw things progress quietly at Cobalt. On the properties, when development was started, work was carried on steadily, and occasional shipments made. With the spring of 1905, however, things put on a new appearance. The mining world had heard a little of Cobalt, and outsiders began to come in. Prospecting began in earnest and new properties were opened. Developed properties began to prepare for more extensive operations. The town of Cobalt began to grow. The obstacles which nature had put in the way were met and overcome. It might be said that up to this time, the discoveries made were accidental; at any rate all had been made on the bare exposed rock.

Systematic work, trenching and clearing away moss, etc., was begun and throughout the known mineral area discoveries of proven value are now numerous.

At present the following are shipping mines. For their relative location a map of the locality may be consulted: The Buffalo Mines (Dennison), the O'Brien Mines, the Earle Mines, the New Ontario (Tretheway), the Savage Mines, the Temiscaming and Hudson Bay, the McKinley and Darragh, the Violet Mine, McLeod and Glendinning, the Watts, the Victoria, the University, the Silver Leaf, the White-Silver, the Kerr Lake Mining Co. (Jacobs), the Drummond Mining Co., the LaRose, the McLeod-Lawson.

Besides these, there are some five or six other properties which are in early stages of development, but which can hardly yet be considered shippers. As to the value and quantity of the output, the writer is not in a position to state with any exactness. It would not be extravagant to place the value at from $2,500,000 to $3,000,000, and the average value per ton at $800 to $1,000. This would give in the neighbourhood of 3,500 tons, or at 20 tons to the car load, 175 car loads.

It is not the purpose of this paper to enter into the geology of the district. A complete description of this is given in the recently published report of the Bureau of Mines, Part II. The ore practically always occurs in small veins of white or pink calcite in a slaty conglomerate rock of the Huronian series. A few veins are however found in the adjoining diabase. The metals occurring in economic quantities in these ores are arsenic, cobalt, nickel and silver. Other metals which have been found associated with these in the same veins are bismuth, copper, iron, lead, zinc and gold. The ore bodies are so variable in their composition that it is difficult to give even approximately the percentages of the metal. However, taking averages off car lots, we may quote the following: Silver, 2 per cent. to 12 per cent.; cobalt, 3 per cent. to 15 per cent.; nickel, 3 per cent. to 15 per cent.; arsenic, 30 per cent. to 60 per cent.

Those who are familiar with the history of the Cobalt camp and what has been accomplished there, have no fear of its future. How-

ever cautious the experiences of other camps in Northern Ontario would teach us to be, there can be absolutely no doubt that Cobalt is a reality. It has already been proven so. The greatest depth that has been reached by any shaft is at the LaRose Mine, where they have gone down to a depth of 185 feet. This alone, so far as this property is concerned, proves its value to be in the millions, while the diamond drill has shewn that 185 feet is far above the known depth of mineral. There are several other shafts down to a depth of 100 feet, and show no sign whatever of giving out.

Up to the present, practically all the ore has gone to New York City and to Newark, N.J. It is shipped in sacks containing from 75 to 150 pounds of ore. This unique ore presents very many difficulties to the smelter. The peculiar combination of cobalt and nickel causes the greatest trouble, and this is augmented by the presence of arsenic. Owing to this fact, up to the present, the producers have not been able to realize the full amount of silver values. They have been able to realize very little on the cobalt and nickel, and nothing at all on the arsenic and other metals above mentioned. The greatest problem that confronts the mines at present, then, is the economical smelting and refining of these products.

The question is often asked, "What is the likelihood of the mineral area widening so as to extend for several miles on all sides of Cobalt?" Like many other questions asked about these deposits, the answer must be one which leaves the enquirer without any added information. The conglomerate rock wherein the mineral most frequently occurs at Cobalt is, roughly speaking, the country rock for fifty miles on all sides. This will seem encouraging to the prospector who is just starting in, and yet perhaps is not much of a comfort to the many who spent the summer of 1905 with shovel and pick and hammer and drill on the rocks of Temiscaming. Cobalt bloom, and in most cases the ore of cobalt (smaltite), have been found in the following places, viz.: west side of Bay Lake (near Trout Lake); on the east side of the Montreal River, near Bay Lake; in Lot 19, Concession IV., Coleman Township, close to Bay Lake; in very many places in Bucke Township; in the Townships of Firstbrook, Dymond,

Hudson, and Lorrain, in several places in Lots 9 and 10, Concession VI., Ingram, and in the unsurveyed territory north of the Townships of Ingram and Pense. It is also reported that the same indications have been found near Lake Kenogami, north of the Township of Burt. From this it would appear that the field is likely to be very large. However, nothing of value has been proved in the case of these last mentioned discoveries, and none of them appear to run above a few ounces per ton in silver values. These facts, however, ought rather to encourage rather than to discourage, when we remember that the first discovery of mineral on Lake Temiscaming was made over a century ago, and is probably what is now known as Wright's Mine on the east shore.

PATENTS, AND THE RELATION OF THE ENGINEER TO THEM.

RUSSELL S. SMART, '04.

The idea of rewarding inventors for the benefits they have conferred on humanity through the exercise of their thought, knowledge and industry, by granting them a monopoly on the making and selling of their invention, has long been recognized as just and equitable. It is in the interest of the community that persons should be induced to devote their time, energies and resources in the development of arts and manufactures. This has been recognized in England from the earliest periods. The right of granting this monopoly rested with the Crown, but we do not find a special enactment relating to it until the "Statute of Monopolies," which was passed during the reign of James the First. As the law and practice with regard to patents became more firmly established, other acts were passed regulating the detail of the grant and the manner in which it was to be applied for. At the same time other countries, recognizing the salutary effect of such a law, made similar statutes, until now there is scarcely a country, no matter how small, that has not its own patent act protecting the rights of inventors in that country.

While all patent laws are passed with the same object, yet they all vary greatly in detail. Thus under the French Patent Law no search is made by the patent office to discover the novelty of the applicant's invention, and thus whether a patent is really valid or not can only be determined in the law courts. In Germany, the United States and Canada, a search is conducted by the patent office to ascertain whether anything similar to the applicant's invention is known or patented, and if there is not, a patent is issued to him. The fact, however, that a patent has been obtained is no guarantee

of the novelty of the invention, as it is quite possible that the Examiner in the patent office may not have knowledge of something in possession of the public which would anticipate the invention. The question then arises as to what a patent is under the Canadian law and what rights it confers on the owner. The patent is primarily a sort of contract entered into between the inventor and the public whereby the inventor, in consideration of having the exclusive right to manufacture, use and sell his invention for a given term of years, agrees to give the invention to the public when the term expires. In Canada further stipulations are made on the part of the public, namely, that unless specially provided for, the invention must be manufactured in Canada within two years, and must not be imported into Canada after the expiration of one year. The first of these conditions is somewhat alleviated by a clause of the Patent Act, whereby an inventor of a complicated machine or a device used only by large corporations may be relieved of the responsibility of manufacturing. In that case he may license others to manufacture if he cannot do so himself.

This clause is generally called the Compulsory License Clause of the Patent Act, and is a great convenience to inventors of this class of devices. When their patents are made subject to it, a condition of the grant otherwise exceedingly difficult and often impossible of fulfilment is dispensed with.

Let us suppose that a patent for some invention has been issued. If others commence to use the invention, the patentee may go to a Canadian court, and if he prove that they are doing so without his permission, the court will compel the infringers to pay damages. It is to be noted, however, that the patent may be attacked by the infringer, and if he can show that the invention was in the possession of the public for more than one year prior to the time of application of the patentee at the patent office, the contract will be declared void. It may be remarked here that a patent that has been litigated and found good is more valuable than before it was tested, for the reason that the patent office, while as accurate as possible, is not infallible. An inventor or the purchaser of a patent is therefore

never sure of the validity of his patent until the Courts have decreed it at the end of a lawsuit.

The novelty of some patents is assured from the fact that they enter an entirely new field. Morse's method of transmitting signals by electric vibrations and Bell's of transmitting sound by a similar means are cases in point. The majority of patents are, however, for minor improvements, and their scope is therefore correspondingly limited. If an inventor makes a great improvement, his patent gives him the greatest right of sequestration, and anything approaching his invention is an infringement. If, however, the amount of invention is small, a mere improvement on old devices for example, his patent will be limited and his right of exclusion will be confined to the particular form of improvement he has made. The value of a patent will, of course, depend on the extent of the monopoly it gives, and there is nothing on the outside to indicate this to us. How, then, are we to determine whether a patent is broad or narrow. There is one part of a patent that will indicate this to us, and that is the claims.

A patent deed consists of four parts. First, the grant which is a document from the government bearing the seal of the patent office giving the patentee the exclusive right to make, use or sell his invention under certain named conditions. Second, the drawings disclosing the invention clearly. Third, the specifications which describe the invention and its mode of operation in such a manner that anyone skilled in the particular art to which it belongs, and desiring to make and use the invention, might do so from the specifications taken with the drawings. This specification enables the public to have the full benefit of the invention after the patent has expired. The fourth part of the patent is the main part, the claims. Here in a number of short paragraphs the inventor specifically points out what he claims as his invention. These claims indicate the scope of the invention and what the inventor is entitled to protect from infringement. The language of the claim is of the utmost importance, as on it the inventor must depend in a law court. Should the inventor fail to claim his invention in sufficiently broad language,

specifying merely the detailed construction of his device, then he will be powerless to prevent others from making that device in a different form, because a court will hold in an action for infringement that the inventor should be protected only in what he has claimed. This clearly shows the necessity for having the claims skilfully drawn. This is the reason also why the patent office recommends the inventor to employ a patent attorney for this purpose.

To illustrate the meaning and value of a claim, let me cite a case wherein a certain dust separator patent was successfully defended in the United States courts. For the account of this I am indebted to a paper by Mr. G. B. Willcox in the Michigan Engineer for 1903. The article under consideration is a device that takes the dust and shavings from the ventilating pipes of a factory, separates them from the air and employs them as fuel. The separator is merely a huge stationary cone of sheet iron placed with the small end down. The air blast from the ventilating fans blows into it tangentially and swirls around inside. The dust flies to the circumference and slides down the cone, dropping into the furnace placed below. The air escapes above. One of the claims of the patent reads as follows: "The combination with a tapering separating chamber of an inlet delivering dust-laden air to the large end of the separating chamber, an air exhaust at the large end, and a depressed dust discharge formed on the side of the tapering chamber and having a discharge-opening at its small end."

This claim is what is called a combination claim, where a number of distinct elements are combined to produce a common result. The claim simply covers the combination of a tapering separating vessel with a suitable inlet spout, air exhaust and discharge-opening. There are no limitations as to how the machine should be constructed. The precise details are immaterial as long as the broad principles remain the same.

By using such broad language in his claims the inventor obtains the legal right not only to prevent others from manufacturing his particular form of dust separator, but to prevent them as well from

manufacturing any form which would come within the wording of his claim. He practically obtained a monopoly on any device in which dust was separated from air by blowing the mixture into a cone and whirling the dust out by centrifugal action.

The courts accept only the literal meaning of the claims, and if an inventor has unnecessarily limited his claims, it is assumed by the court that he has dedicated the broad invention to the public. Very few inventors realize the true meaning and value of their claims. They assume that everything shown and described in the specifications and drawings is their invention and that they have an exclusive right to it. This often leads inventors to place an excessive value on their patent when endeavouring to sell it.

Considering the relation of the engineer to patents and patent law, it would seem to me that there is much in common between them. The objects toward which both aim are practically the same, namely, to promote the progress of all arts and sciences. The engineer comes in contact with the invention generally at the embryo stage and much of its future value depends on his handling of it. In his work the engineer uses patented appliances, and most engineering contracts and specifications contain special clauses relating to the patent side of the transaction. The engineer, then, should be ready in a general way to tell whether or not a device is covered by a given patent and so be enabled to steer clear of any infringement suits arising out of the manufacture of a patented invention. Then he should endeavour to safeguard the interests of his firm in the workshop by having drawings of new inventions properly dated and witnessed and by other protective steps. Nothing is more difficult and yet more important in a lawsuit than to be able to prove exactly when the invention was first thought of and when the first workable machine was made. The engineer, too, should be able to estimate properly the value of a patent, so that if purchasing, his firm will not pay an exorbitant price, and if manufacturing will not pay an excessive royalty.

The value of a patent, as I before pointed out, depends almost entirely on the scope of its claims, and this the engineer in a general

way should be able to determine. Of course this determination would in no way interfere with the exhaustive validity reports which large firms have made by their patent attorneys before they purchase any patent of value. These reports are comprehensive, and the engineer's position would be to advise whether such a search should be made or not. At the present time it is very unwise to pay a large sum for any patent before an expert opinion has been obtained as to its value, and before an exhaustive search has been made through the patent records. It is not well to rely on the search the patent examiners make, as their facilities for doing this, especially in Canada, are very much limited. Very frequently in the United States, patents are found to be anticipated by old patents which the examiners have overlooked. When it is realized that an examiner in Canada has to examine about one hundred cases a month, it will be understood that no great amount of time can be devoted to each. An engineer who could intelligently advise his employer whether a certain patent would be a good investment, and could point out what features of the invention were covered by the patent and what were not, would be rendering valuable professional services, and would frequently be able to save his employer large sums of money.

THE SCHOOL OF SCIENCE OBSERVATORY.

L. B. Stewart, O.L.S., D.T.S.

Professor of Surveying.

There are possibly some students still in attendance at the School who have seen the evolution of the astronomical observatory here illustrated, from a simple stone pillar on which an alt-azimuth could be mounted, through the form of a small observing shed just large enough to contain the observer in addition to the instrument, to the present more commodious building. It is to be hoped also that the future will witness a still further development into a more substantial structure, placed upon a more convenient site, as the present building is regarded as only temporary, designed to meet immediate wants.

The object of the observatory is to afford instruction to students in geodetic astronomy, or that part of practical astronomy that is practised in connection with a geodetic survey, viz., the precise determination of time, latitude, longitude, and azimuth. The equipment for carrying on this work at present comprises an alt-azimuth, a zenith telescope, a transit instrument, an electro-chronograph, an astronomical mean-time clock, and a sidereal chronometer, as well as other minor accessories, such as an arithmometer for facilitating computations. The clock and chronometer are at present housed in a room in the basement of the engineering building, where the temperature can be kept more uniform, and each is provided with a break-circuit attachment, so that it may be used in connection with the chronograph.

The alt-azimuth and the zenith telescope are by Troughton & Simms, the former having a telescope of 2 ins. aperture and 19 ins. focal length, and being provided with horizontal and vertical circles 10 ins. in diameter divided to 5′ spaces, which are further subdivided by opposite reading microscopes to single seconds; and the latter having a telescope of $2\frac{1}{2}$ ins. aperture and 24 ins. focal length. The transit instrument is by Cooke, and has a telescope of 3 ins. clear aperture and 36 ins. focal length. In its focus is a filar micrometer which may be turned through a right angle between stops, so that it is designed for the measurement of differences of zenith distance as well as of hour angle. The object of this is to adapt the instrument for the determination of latitude by Talcott's method, a precise level being attached to one of the finding circles.

The observatory itself contains two rooms, one of which—12 ft. by 24 ft. in size—is the observatory proper, and contains three brick piers, upon which the three instruments above described are mounted. The middle pier is covered by the revolving dome, and on it the alt-azimuth is set, which can therefore be used for a variety of work, such as time by meridian transits; latitude by meridian zenith distances, prime vertical transits, or observations of stars at elongation; and azimuth determinations. The zenith telescope and the transit instrument are mounted on the two side piers, and transit openings in the roof of the observatory afford access to the heavens.

Up to the present time there has been little inducement for students to engage in astronomical study, there being so few openings for men who have been trained for that class of work, as Canada has at present no systematic topographic survey based upon a primary triangulation. There is no doubt, however, that in the near future such a survey will be inaugurated, as its value to the country is gradually coming to be recognized. Our government has been memorialized by the various professional, scientific, military, and other organizations, and by the universities, urging them to commence a geodetic survey; and a few years ago the United States government requested the governments of Canada and Mexico to undertake the measurement of the portions of the 98th meridian lying

within their respective domains, pointing out the value that such measurement would be to science. Mexico has complied with the request, but Canada has not yet done so; and as the part of the 98th meridian within Canada does not traverse that portion of the Dominion of which topographic maps are most needed, it is not likely that geodetic work will begin there.

The importance attached by other civilized nations to the possession of accurate topographic maps is shown by the fact that Canada stands alone, with Turkey and some of the South American republics, in not having a trigonometric survey either completed or in progress.

In view of these facts it is clear that the need of men trained in the methods of a geodetic survey will be felt in the near future, and the writer has always urged that the School should be prepared to give students the instruction necessary to enable them to engage in such work.

TRACK ALIGNMENT ON MAINTENANCE.

A. J. Latornell, '03.

Perfect line is one of the essentials of good track. Not only is true alignment necessary to economy of maintenance, but it is also requisite to the easy and safe running of trains at the high speeds which modern transportation demands. Kinks on tangents, even though slight, or irregularities on curves, cause an unpleasant side surging, which at high speeds and in aggravated cases may even lead to derailment.

On new work stakes are set by the engineer at intervals of 100 feet on tangents and 25 to 50 feet on curves, according to the sharpness of curvature. When the road is in operation, these track centre stakes soon become destroyed, and the effect of traffic is to cause the track to shift more or less, especially at the *B. C.*'s and *E. C.*'s if transitions are not used. If only the foreman's eye is to be depended upon, marked changes from the original alignment will gradually develop. Curves will inevitably change and swings will appear on long tangents, since no trackman's eye is sufficiently accurate to prevent the occurrence of such things. For a thorough relignment of a piece of track, the transit should be used and the track centres marked by tacks in stakes driven firmly into the ground. These stakes are set every 100 or 200 feet on tangents and every 25 or 50 feet on curves, depending, as in new work, on the sharpness of the curve in any given instance.

Theoretically, at the time of construction, the *B. C.* and *E. C* of every curve should be marked by reference stakes in order that

these points may be conveniently located at any subsequent time. In addition to this, in order to re-establish tangents, a sufficient number of points thereon should also be marked by reference stakes. If this were always done, so that these points might be picked up readily when required, all subsequent re-running of track centres would be a comparatively short and simple matter, it being, of course, assumed that the original field notes are on file and accessible. But in a great many cases these reference stakes, even when set, have not been preserved, so that the location of the essential points is not definitely fixed. In this paper it will be assumed that no information is obtained from original field notes or plans and that no reference stakes can be found on the ground. This is a case that is often met with in practice, except that the degree of the curve and the intersection angle may generally be obtained from right of way or other plans. As it is always necessary in re-running track centres to check these on the ground, we may for all practical purposes assume that they, too, are unknown. It may generally be pretty safely assumed that the original centre line will be much better preserved on tangents than on curves, and very little trouble will be met with in this part of the work. It is true that successive linings by the track foreman may have introduced bends and swings, but certain ruling points may be chosen, such as bridge centres, where it is likely that the original centre line has been preserved. In running tangents the best method is to establish a target in the centre of the track, high enough to clear trains, and as far ahead of the initial point of setting the instrument as can be distinctly seen. Care must be taken that that point of the target to which the telescope of the instrument is to be directed is exactly over the centre of the track, i.e., the centre to which the track is to be lined. The initial point of setting the instrument should be chosen at some point where the original centre line is pretty definitely known. Then the direction of the tangent may be established by directing the telescope to some other point which is known to be also on the original centre line. By sighting each way from the initial point along this line, it may be seen how nearly this coincides with the centre line of the existing

track. Unless there has been a bend in the original alignment, it will generally be found that the maximum shift of track required is not too great, and centre stakes may then be set quite rapidly along this line. When it is found that a tangent has crooks or bends which it is impossible to remove without shifting the track too far to one side of the roadbed, these bends should be carried to the summits of grades and the change in direction made there. These are usually so slight that they do not affect the smooth running of trains, but if left where they may be seen give an unsightly appearance to the track. At the summits of grades they are partially if not altogether hidden.

The most difficult part of the work is the centering of the curved portion of the track where none of the curve elements are known

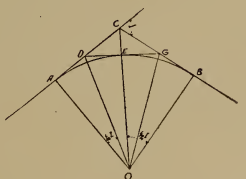


Fig 1

definitely. If the centres for the tangents on each side of the curve have been set and their direction thereby established, the change of direction from one of these to the other will give us our angle of intersection (I), although we may not be able to measure it directly by setting the instrument at the $P\ I$. However if the two tangents can conveniently be produced to the point of intersection, we can by setting up at this point obtain at once the angle desired. At the same time, we may obtain the degree of curvature by measuring the distance from the point of intersection to the centre of the track in the direction of a line which bisects the angle between the two tangents. It is evident that this line if produced would pass through the centre of the circle of which the curve forms an arc.

In Fig. 1, $C\ E$ represents the part measured.

Now $A\ D = D\ E = E\ G = G\ B = R\ tan\ \frac{1}{4}\ I.$

Also $C\ E = D\ E\ tan\ \frac{1}{2}\ I.$

$\therefore C\ E = R\ tan\ \frac{1}{4}\ I.\ tan\ \frac{1}{2}\ I$, since $D\ E = R\ tan\ \frac{1}{4}\ I.$

$$\therefore R = \frac{C\ E}{tan\ \frac{1}{2}\ I.\ \ tan\ \frac{1}{4}\ I.}$$

Then R being known, the degree of the curve is known and the tangent distance may be obtained from the equation.

$T = R\ tan\ \frac{1}{2}\ I.$

The position of the $B\ C$ and $E\ C$ are then located by measuring the distance T along the tangents each way from the $P\ I.$ The curve may then be run in by deflection angles in the usual way. As both the degree of the curve and tangent distance depend on the measured distance $C\ E$, their calculated values will be slightly in error if the present centre at the point E differs much from the true centre. However, in this case it will generally be found that the degree of the curve as calculated will differ by a few minutes from some regular integer such as three degrees or four degrees. Hence by adopting this latter value for the degree of curve and calculating the tangent distance from this, we will likely find that the curve thus obtained fits our road bed very well.

Although producing the tangents to intersection is much the simpler way, since it does away with a good deal of calculation in the field, yet it frequently happens in maintenance work that it is exceedingly inconvenient and often impossible to adopt it. Aside altogether from topographical difficulties, tangents when produced may lead through farmers' grain fields or be obstructed by buildings. Sometimes indeed the location of the point of intersection itself is occupied by a building. In this case the problem requires a different solution. The following is a method:

In Fig. 2, let $V\ A$ and $B\ W$ be two tangents whose direction we know, but whose point of intersection is inaccessible. We desire to determine I, T, R and the position of the $B\ C$ and $E\ C$.

A and *B* are two points on the tangents near the *B C* and *E C* respectively. *A D*, *D E*, *E F* and *F B* is a traverse connecting the points *A* and *B*. This traverse may be carried out by assuming *V A* to be a meridian. (Any other bearing whatever may be assumed for this line.) Then by setting up the transit at the points *A*, *D*, *E*, *F* and *B*, we may obtain the bearings of *A D*, *D E*, *E F*, *F B* and *B W*. Now the difference of bearing of *V A* and *B W* is equal to their change of direction, i.e., the difference of bearing of *V A* and *B W* = *I*.

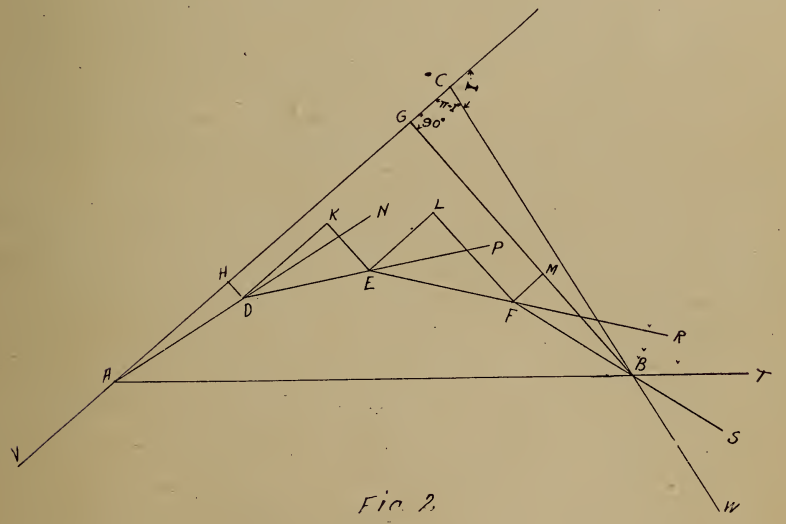


Fig. 2.

A D, *D E*, *E F* and *F G* are measured so that the bearing and distance of each of these lines is known. Draw *B G* perpendicular to *A C*. Now, knowing the bearing and distance of *A D*, *D E*, *E F* and *F G*, we can by the usual method of latitudes and departures find the distances *A G* and *G B*. It is evident that *A H*, *D K*, *E L* and *F M* are the latitudes of *A D*, *D E*, *E F*, and *F B* respectively.

Then $A\ H + D\ K + E\ L + F\ M = A\ G$.

Similarly $D\ H + K\ E + L\ F + M\ B$ (sum of departures) $= B\ G$.

In triangle $G\ C\ B$ the angle $B\ C\ G = 180° - I$ and $G\ C = B\ G\ cot\ B\ C\ G$.

Also $C\ B = \dfrac{B\ G}{sin\ B\ C\ G.}$

Thus we can find $G\ C$ and $B\ C$.

Then $A\ C = A\ G + G\ C$.

Thus knowing the distances $A\ C$ and $B\ C$, we will know the distance of the points A and B from the $P\ I$. Knowing T, we can locate the $B\ C$ and $E\ C$ of our curve by measuring along the tangents in either direction from A and B, lengths sufficient to locate these points at a distance T from the $P\ I$. For example, suppose $A\ C$ is greater than T. Then by measuring back on $A\ C$ a distance $A\ C - T$, we will find the position of the $B\ C$. Similarly if $A\ C$ is less than T, we measure from A towards V a distance $T - A\ C$. In the same way the $E\ C$ is located.

To find T we first find D (degree of curve) by taking a number of deflections for 100-foot chords. This method, although not strictly accurate, being based on the present alignment of the curve, will yet enable us to arrive at a very close approximation to the true value of D. The magnitudes of the deflections at the central portion of the curve are more likely to be correct. Knowing D from these deflections, we find T from the equation $T = \dfrac{50\ tan\ \frac{1}{2}\ I.}{sin\ D.}$

The curve may now be run in in the usual way as a trial curve. It is quite probable that the first or trial curve will be found to vary too much from the centre line of the existing track, and that it will be economically impossible to line it to these centres. If all the instrumental work and calculations have been done correctly, the curve should end on the $E\ C$, however much the central portion of the curve may be in error. It is sometimes necessary to change the curve to fit it to the road-bed, or to cause the line of the track to cross the centre of a bridge or culvert that may be located on it. This may be done by changing the degree of the curve, shifting the $B\ C$, etc. If it can be avoided, it is best not to depart from the usual degree

of curves, that is, to use one such as three degrees and fifty-eight minutes, or introduce other irregularities of a similar kind.

When the track is re-lined in this way the essential points should be properly marked by reference stakes so that they may be easily located at any future time. If these centre stakes were kept permanently set for the guidance of trackmen in lining track, and their positions checked over once a year, so that any destroyed or displaced might be re-set, it would result in a much better alignment of track.

It will be noted that in the preceding, no reference has been made to transition or casement curves. It is not, however, to be inferred that these are not considered as necessary adjuncts to perfect alignment, but rather that they would be the next step in the process. Before these are applied, the tangents and circular curves must be staked out on the ground. It will be seen by reference to the many methods describing the application of transition curves to existing track, that it is assumed that tangents and circular curves are established. However, as one method of applying transition curves to a previously staked-out centre line was described in last year's issue of this pamphlet, and as the importance of this curve has lately brought out many hand books fully describing methods of applying such curves to existing track, and containing all tables necessary for their use, at the risk of incompleteness they will be omitted from this paper. Transition curves are now being applied to the tracks of all first-class roads, and when once adopted their use is never discontinued on any account. Not only do they contribute to the easy and safe running of trains, but the track keeps in line much better when they are used than when they are not.

Assuming then that transition curves have also been staked out, the next operation is the shifting of the track to these centres. This is done by means of lining bars. Trackmen with bars are placed at the joints, quarters and centres of the rails. The gauge is placed on the rails near the centre stake and the track is thrown until the centre mark on the gauge coincides with the tack in the centre stake. The men are then moved to another stake and the operation repeated. The track between the stakes is lined by eye, following which the line should be checked at the centre stakes. Only one of the two rails

is lined, so that in holding the gauge on the track for lining it must be pressed against this rail. This insures that the rail in question will be exactly half the width of the gauge from the centre stakes. On curves the outside rail is the one lined, and the extra width of gauge required is obtained by moving the inside rail outward. After the one rail has been lined to the centre stakes, the other rail is lined to this one by means of the gauge, this operation being known as gauging.

This work of relining is one that is continually necessary as the track is constantly being thrown out of line by traffic. It is usually

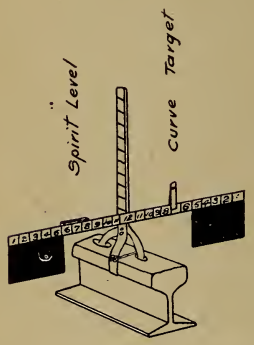


Fig. 3
Track Sighting Block.

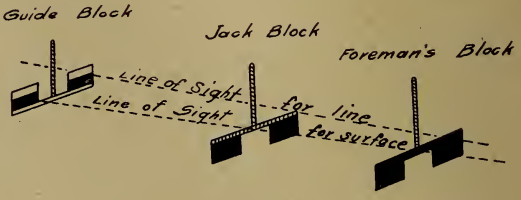


Fig. 4.
Method of Using Track Sighting Blocks

done by eye, yet sometimes "sighting blocks" are employed. In Fig. 3 is shown the surfacing and lining blocks invented by Mr. John M. Bailey, of Danville, Ky., and designed to meet the requirements of efficiency and economy in work. They are now in use on the Louisville and Nashville Ry., and on other railways throughout the United States.

There are three blocks to a set, each having an upright frame and a cross-arm, made of inch No. 12 hoop steel. Each cross-arm has a pair of flags or targets of thin sheet metal. The parts are all enamelled, varnished and baked, which treatment is more effective than painting to protect them from scratching or wear. The parts

of each block fold together when not in use. Each upright has two legs resting on the rail head and a side piece clamped against the side of the rail by a thumb-screw as shown in Fig. 3. The "foreman's block" has the flags turned down and the flags and cross-arm painted black. The "jack block" is similar, but with a graduated arm for use in lining curves as shown. The "guide block" has the flags turned upward and is painted white with a black stripe across the flags. This makes it distinct at a distance, and the black stripe forms the guide line as shown in Fig. 4.

In sighting for line, the sight is taken along the outer ends of the flags, the men with the lining bars being stationed at the middle or jack block. The two outer blocks being on the correct line, the track at the middle or jack block is shifted until this block is brought into range. In lining a curve of known degree the foreman's block and guide block are placed 62 feet or 100 feet apart, and the jack block midway between them. A small red target is then fitted on the graduated cross-arm to mark the middle ordinate of that degree of curve for 62 feet or 100 feet as the case may be, and this used for sighting instead of the outer end of the target. The 62-foot chord is most commonly used by trackmen in lining, as the middle ordinate in inches is the same as the degree of the curve. Thus for a 62-foot chord on a four-degree curve, the middle ordinate is 4 inches. These blocks may also be used for checking the line on curves at any time. Commencing at the point of curve (or point of circular curve if there is a transition), the blocks being placed as above described, the red target is moved along the graduated arm until brought into the line of sight and the middle ordinate is then read on the graduated arm. Continuing around the curve, middle ordinates may be obtained at intervals of 31 feet (or 50 feet if 100-foot chords are used). These middle ordinates being recorded on a piece of paper, or at the various points on the rail, it will be seen at once where the curve is too flat or too sharp. The track can be thrown subsequently as required.

CONCERNING CHIMNEYS.

P. Gillespie, B.A. Sc.

The factory chimney exists primarily for the purpose of creating a draft of air through the fire. In its modern form, though indispensable from the mechanical standpoint, it is usually in quite a different category from the Tuscan column or the Gothic arch. One test of beauty is that of usefulness, but it by no means follows that all things useful are beautiful. The chimney is typical of a class of structures that do not lend themselves greatly to architectural display. The basis of its design must be its fitness to perform the work required of it, and hence of necessity it is utilitarian first, æsthetic afterwards if at all.

Two things that, prior to all others, concern the designer of a chimney are the height and internal sectional area. These will vary with the volume of gases to be discharged and the draft desired. The problem is usually stated as follows:—"For a given horse-power, what are the height and cross-sectional dimensions of the chimney that will be required?" Since the consumption of fuel will vary with the horse power directly or nearly so, the problem may be stated in this way:—"Given the consumption of coal per hour, to find the height and cross-section of a suitable chimney."

The draft of a chimney, as is well known, is due to the excess of weight of a column of external air over that of the heated column of equal height contained in the chimney. The flow of air is due to much the same causes that produce a current of water in the piping of the heater on a kitchen range. Many mathematical investigations

based on thermodynamic fundamentals have been proposed, Rankine, Peclet, Wood and Pinzger being the best-known contributors. The unfortunate feature, however, has been lack of agreement among the results obtained, due, doubtless, to differences in the logical substructure and in the assumptions made by those who have assayed to reduce the problem to a mathematical basis. We are forced to the conclusion that the problem of chimney draft is one difficult of satisfactory treatment in a purely theoretical way. The results obtained, however, have been modified by experiment and experience, and form the basis of empirical formulæ which are employed in design. With no attempt to indicate how these results are arrived at, the following "rules" are given as being typical. They are those of Professor Gale, and are taken from Christie's "Chimney Design." The quantities contained in the subjoined table are obtained from the formulæ quoted. These are said to agree very well with modern American practice.

Where F is the fuel consumption in lbs. per hour,
R is the fuel consumption in lbs. per sq. ft. of grate per hour,
G is grate area in sq. ft.,
T is temperature of chimney gases in degrees Fahr.,
a is grate opening area in sq. ft.,
H is height of chimney in feet, and
S is the sectional area of chimney flue in sq. ft.

$$G = \frac{F}{R}$$

$$a = 0.4\ G.$$

$$H = 100\ \frac{0.2}{T}\left(\frac{F}{a}\right)^2.$$

$$S = \frac{F}{60}$$

The following table has been calculated on an assumed consumption of five lbs. of coal per H. P. per hour, a rate of consumption per sq. ft. of grate area as given in column No. 3, and a temperature of chimney gases of 500° F.

PROFESSOR GALE'S CHIMNEY TABLE.

H. P.	Coal per hr. lbs. *F*	Coal per sq. ft. of grate per hr., lbs. *R*	Grate area. sq. ft. *G*	Grate opening area. sq. ft. *a*	Height. ft. *H*	Chimney cross section area. sq. ft. *S*
20	100	13	7.7	3	44	1.6
60	300	15	20	8	56	5.0
100	500	17	30	12	70	8.3
200	1,000	19	53	21	90	16.6
400	2,000	21	95	38	111	33.3
600	3,000	23	130	52	133	50.0
1000	5,000	25	200	80	156	83.3

In the design of the foundation of a chimney, as of that of any other structure, the aim will be to prevent settlement, and especially unequal settlement. On foundations much has been written, and it would seem as though little remains unsaid. The character of the foundation and its size will depend on the character of the soil upon which the chimney is to be erected. The following safe loads in tons per sq. ft. for various materials represent what experience has shown to be good practice:—

Quicksand, $\frac{1}{2}$ ton.

Sand, 4 tons.

Clay, 4 tons.

Gravel, 8 tons.

Solid rock, 200 tons.

The bounding planes of the sides of the foundation should be inclined outward, extending the bearing area so that the maximum allowable stress may not be exceeded. In cases of soft soil, piling may be necessary. The piles will carry, as is usual, a grillage, or their heads will be imbedded in concrete.

It is often advisable to have a lining to a concrete or brick chimney. This lining usually takes the form of an independent shaft concentric with the outer shell, and should be separate from the latter to permit of independent contraction and expansion. The material of which it is constructed should be sufficiently refractory to resist the high temperature of the chimney gases. It may or may not

extend to the top as is thought advisable. Its thickness is usually much less than that of the chimney proper.

There are two items which enter into the discussion of chimney stability. The first is the weight of the chimney, and the second is the action of wind. The line of action of the weight of material above any horizontal cross-section in a chimney symmetrically built of homogeneous materials, will be through the centre of gravity of that section. The effect of the wind action about any such section is to create a moment. Now a couple and a single force are the equivalent of this same single force at a new point of application. In other words, the effect of the wind is to shift leeward the point of application of the force which represents the weight. In short, we have a case of eccentric loading at the cross-section, the amount of the eccentricity depending of course on the magnitude of the couple created by the wind. A reference will be all that is necessary to recall to the reader's mind that a uniformly varied stress is the necessary concomitant of eccentric loading, and hence the usual equations applying thereto may be used in this instance. In certain cases, brick chimneys for example, it is important that the eccentricity be not greater than would produce a zero stress at the windward side. This is tantamount to saying that the maximum stress (i.e., on the leeward side) will be double of that at the centre of gravity of the cross-section.

Where x_0 is the eccentricity of the load, i.e., its distance from the *C. G.*

$\bar{p}$ is the average stress at the section, i.e., the stress at the C. G.,

$p_{max.}$ is the greatest stress at the section, x_1 is half the outside diameter of the shaft, and

k is the radius of gyration of the cross-section,

$$\frac{\bar{p}}{p_{max}} = \frac{1}{1 + \frac{x_0 \, x_1}{k^2}}$$

In order that p may be half of $p_{max.}$ and therefore that $p_{min.}$ may be zero,

$$\frac{1}{1+\frac{x_0\ x_1}{k^2}} = \frac{1}{2}$$

From this $x_0\, x_1 = k^2$

and $x_0 = \dfrac{k^2}{x_1}$

Let us consider the case of a hollow circular chimney whose outer and inner diameters are respectively $2x_1$ and $2x_2$.

Remembering that $I = k^2 A$ where I and A are respectively the moment of inertia and area of the cross-section, we obtain

$$x_0 = \frac{k^2}{x_1} = \frac{I}{x_1\, A} = \frac{\frac{\pi}{64}\left\{ (2x_1)^4 - (2x_2)^4 \right\}}{x_1 \frac{\pi}{4}\left\{ (2x_1)^2 - (2x_2)^2 \right\}}$$

$$= \frac{(2x_1)^2 + (2x_2)^2}{16\ x_1} = \frac{x_1}{4} + \frac{1}{4}\frac{{x_2}^2}{x_1}$$

$$= \frac{2x_1}{4} \text{ where } x_2 = x_1.$$

This may be interpreted as meaning that the limiting position of the point of application of an eccentric load on a horizontal section of a cylindrical chimney with thin walls, in order that no tension may result in any part of the cross-section, is distant from the centre of gravity of the area, $\frac{1}{4}$ of the diameter. The point of application of the load is sometimes called the centre of resistance. Similarly, it may be shown that for a square chimney with external and internal diameters of $2x_1$ and $2x_2$ respectively, x_0 approaches the limit $\dfrac{2x_1}{3}$ as the thickness of shell becomes less and less.

Rankine defines the moment of stability of a structure as follows:—"The moment of stability of a body or structure supported at a given plane joint is the moment of the couple of forces which must be applied in a given vertical plane to that body or structure in

addition to its own weight, in order to transfer the centre of resistance of the joint to the limiting position consistent with stability." It is manifest from the above that Rankine intended his definition to apply especially to structures the material of which is incapable of resisting tension. To other structures, notwithstanding, the term may be applied; and that in such cases it is an extremely useful quantity, we shall subsequently endeavour to show. From what has been said, it is at once apparent that where W is the weight of the structure and x_0 the horizontal distance from the centre of gravity of the cross-section to the limiting position of the centre of resistance, $W x_0$ will be the moment of stability.

The relation between wind velocity and wind pressure has a practical as well as a scientific interest; yet since in design, it is for maximum stresses that we must provide, and frequently against abnormal conditions that we must safeguard, there is but one velocity—and that the greatest—in which we are really concerned. Smeaton gives the following rule for determining the pressure due to wind:—

Where p is the pressure in lbs. per sq. ft., and

v is the velocity in miles per hour,

$$p = \frac{v^2}{200}$$

On this assumption, the following table has been constructed:—

SMEATON'S WIND TABLE.

v Miles per hour.	p Pds. per sq. ft.
2	.02
4	.08
12	.75
25	3.00
30	4.50
35	6.00
40	8.00
45	10.00
50	12.50
60	18.00
75	28.20
80	32.00
90	40.50
100	50.00

It will be generally admitted that the effectiveness of wind will be reduced if the surface upon which it acts be curved or oblique to the direction of the wind. Wilson gives the following:—

Pressure on a square tower assumed = 1.

Pressure on a hexagonal tower = $\frac{3}{4}$

Pressure on an octagonal tower = $\frac{6\,5}{1\,0\,0}$.

Pressure on a circular tower = $\frac{1}{2}$.

Taking the maximum wind pressure on a plane surface as 50 lbs. per sq. ft., that on the projection of a cylindrical tower would be but half that amount.

Let us suppose now that a chimney is acted upon by wind, the net effect of which is a force P acting at a point h above some horizontal section under consideration. It is apparent that the moment due to wind action is Ph. Now if Ph be less than Wx_0, the entire cross-section will be in compression since the centre of resistance will not be thrown to its limiting position. If Ph be equal to Wx_0, then the line of zero stress at the section will be at the windward side, and the compressive stress on the leeward side will be exactly double of the stress at the centre of gravity, or to speak more correctly, will be double of the stress along a line in the section passing through the centre of gravity transverse to the direction of the wind. If, on the contrary, Ph be greater than Wx_0, the effect will depend on the character of the material of which the tower is built. If of material incapable of resisting tension, the effect will be to reduce the effective area of the cross-section in resisting stress. If the material be capable of resisting tension, the effective area subjected to stress will not be reduced, the stress at the centre of gravity will remain constant and the neutral line will lie within the area. To the latter class of structures belong steel and reinforced concrete.

The factory chimney constructed of reinforced concrete is designed to resist tension as well as compression. The excess of the wind moment over the "moment of stability" so-called, is the quantity producing on the windward side a tension which is assumed to be wholly resisted by the steel embedded in the concrete. In what

follows, the calculations leading to the design of the reinforcing of a chimney in a typical case are given. On page 298, "Reinforced Concrete," by Buel and Hill, is a zinc etching showing the construction of a factory chimney lately erected at Jersey City, N.J. This was selected as being representative of such structures. Certain assumptions having been made, the computations as given below determine what would be considered an adequate reinforcing. Lack of space will not permit of a discussion of the many other features in chimney design here exemplified. The courtesy of the Engineering News Pub. Co. in kindly permitting the reproduction of the etching above referred to is gratefully acknowledged.

As may be seen from the figure, the chimney stands 100 ft. above ground and has a constant outer diameter of 11 ft. 4 in. It consists of an inner and an outer shell, the former being practically independent of the latter. The outer shell has a thickness of seven inches for the first 30 ft. of its height, a thickness of six inches for the next 30 ft., and for the last 40 ft. the outer radius is but 5 ins. longer than the inner. The vertical reinforcing of this shell will be considered, and that at section E F only. The following assumptions will be made:—

1. That concrete weighs 140 lbs. per cu. ft.

2. That the maximum pressure due to wind is 50 lbs. per sq. ft. on a plane surface.

3. That wind pressure may be considered as acting at a point half the height of the tower above ground where the width is constant.

4. That the entire tension in the chimney due to wind is borne by the steel, for which a maximum allowable tensile stress will be taken as 12,000 lbs. per sq. in.

To compute the weight of the outer shell:—

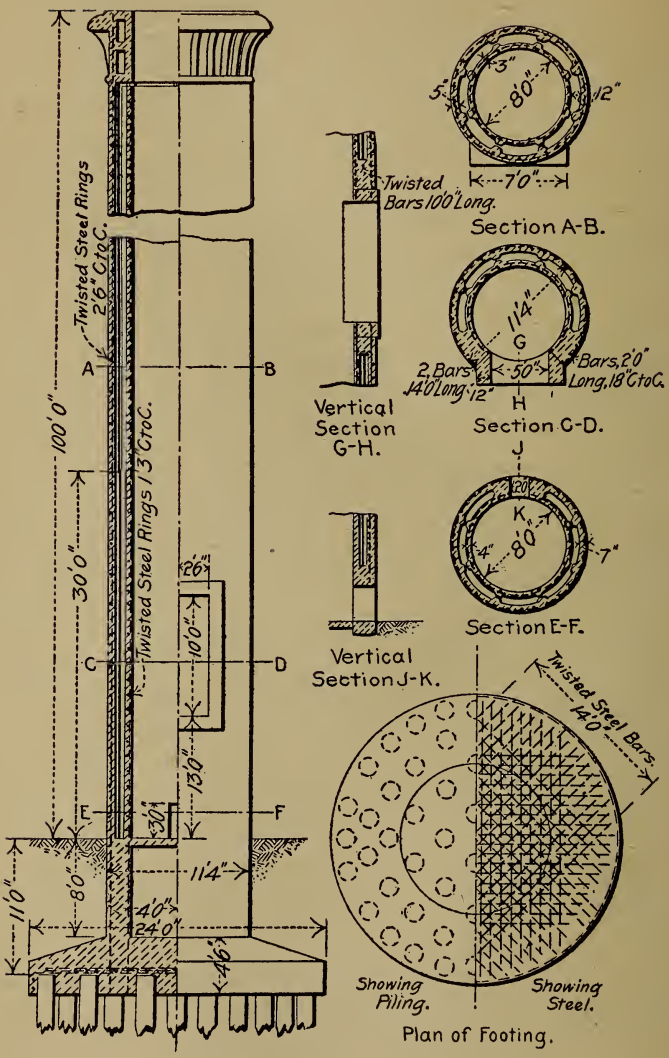
Outer dia. = 11 ft. 4 in. = 136 inches.

Inner dia. = 10 ft. 2 in. = 122 inches.

Area of outer circle = 14,526 sq. ins.

Area of inner circle = 11,689 sq. ins.

Diff. (area of annulus) = 2,837 sq. in.


Twisted Steel Rings 2'6" C to C.
Twisted Steel Rings 1'3" C to C.
100'0"
30'0"
A
B
C
D
E
F
26"
10'0"
30"
11'0"
8'0"
11'4"
4'0"
24'0"
4'6"
3"
5"
8'0"
1/2"
7'0"
Twisted Bars 100' Long.
Section A-B.
11'4"
G
H
2 Bars 140' Long 12"
50"
Bars 2'0" Long, 18" C to C.
Vertical Section G-H.
Section G-D.
J
K
20"
4"
8'0"
7"
Section E-F.
Vertical Section J-K.
Twisted Steel Bars 14'0"
Showing Piling.
Showing Steel.
Plan of Footing.

Wt. of sec. 30 ft. high $= \frac{2,837}{144} \times 30 \times 140 =$ ..... 82,746 lbs.

Similarly, weight of second section 30 ft. high = 71,458 lbs.

And weight of third section, 40 ft. high = ... 79,994 lbs.

Total weight = ... 234,198 lbs.

Wind pressure $= \frac{1}{2}\ (11\frac{1}{3} \times 100)\ 50 = 28,333$ lbs.

Height of point of application of wind above ground = 50 ft. = 600 ins.

To obtain the value of the moment of inertia of the cross-section.

$$I = \frac{\pi}{64}\left\{ (2x_1)^4 - (2x_2)^4 \right\}$$

$$= \frac{\pi}{64}\left\{136^4 - 122^4\right\} = 5,907,859.$$

To find the value of the square of the radius of gyration of the cross section:

$$k^2 = \frac{I}{A} = \frac{\frac{\pi}{64}\left\{ (2x_1)^4 - (2x_2)^4 \right\}}{\frac{\pi}{4}\left\{ (2x_1)^2 - (2x_2)^2 \right\}} = \frac{(2x_1)^2 + (2x_2)^2}{16}$$

$$= \frac{136^2 + 122^2}{16} = 2086.$$

To find the maximum value of x_0 (the eccentricity) in order that no tension may result in the cross-section.

$$x_0 = \frac{k^2}{x_1} = \frac{2086}{68} = 30.6 \text{ in.} = \text{say } 31 \text{ ins.}$$

Moment of stability $= Wx_0 = 234,198 \times 31 = 7,260,138.$

Moment of wind $= 28,333 \times 600 = 16,999,800.$

Excess of moment of wind over moment of stability = 16,999,800 —7,260,138 = 9,739,662.

This may be designated the bending moment.

Employing the well-known beam formula, $\frac{p}{y} = \frac{M}{I}$ and noting that for the case in hand,

$y = 68$ ins.

$M = 9{,}739{,}622$, and

$I = 5{,}907{,}859$,

we find the value of p to be $\frac{9{,}739{,}662 \times 68}{5{,}907{,}859} = 112$ lbs. per sq. in.

Remembering that as the wind may approach from any side, the total tension to be provided against will be approximately

$p\,A = 112 \times 2{,}837 = 317{,}744$ lbs.

At 12,000 lbs. per sq. in., this would necessitate the employment of $317{,}744 \div 12{,}000 = 26.5$ sq. ins. of metal.

If $\frac{3}{4}$ in. sq. rods are used, the number of vertical pieces becomes $\frac{26.5}{\frac{3}{4} \times \frac{3}{4}} = 48$ rods nearly.

Similarly, computations may be made for sections $C - D$ and $A - B$.

OBITUARY NOTICES.

J. HARVEY HALL.

On the 14th of August, 1905, the School lost one of its most promising undergraduates in the death of J. Harvey Hall, a member of the class of '07. Our late lamented friend was attacked in January, 1905, with a disease of cancerous nature, which developed quickly, but which was not diagnosed as such until after the annual examinations. From January until April he suffered a great deal of pain, but heroically kept to his work and succeeded in completing his year very creditably.

In the hope that an operation might bring relief, the leg was amputated on the 6th of May. This was followed by what was thought to be a complete recovery, but latterly, the disease manifested itself in the lungs and the patient passed away on August 14th. His illness was of long duration and the pain constant and acute, yet none of his fellow students ever heard a murmur from his lips.

Harvey was born in Toronto in 1885, and received his early training at Queen Victoria Public School. Later he matriculated from Parkdale Collegiate, and began his course at the School of Science. Harvey was not of the kind that make many friends, but those who knew him best saw in him an unswerving honesty of purpose and devotion to high ideals, which, had he been spared, would have brought him forward in after years as an honour to the School and to the profession.

DRYDEN LE ROY NIGHSWANDER.

Last summer, while working at his home, Mr. Dryden Le Roy Nighswander, of Kenora, contracted typhoid fever, which resulted in his death on August 14, 1905. He entered the School of Practical Science in October of 1904, and during the year he spent at the School, by his application, his thoroughness and his manifest ability, he gave promise of a life successful beyond the average. His bright agreeable manner, and his conscientious adherence to what was right, served to make him one of the popular men of the class of '07, and to those who knew him best, his sterling qualities and moral character made him one whom it was good to know.

WALLACE McGREGOR.

Life's uncertainty was once more sadly impressed on the many student friends of W. Wallace McGregor by his death from typhoid in the month of October, 1905. Being of robust appearance, and no report of his serious illness having reached the school, the unexpected intelligence of his having passed away came as a shock to us all. After his graduation in the spring of 1905, he was employed by the firm of DeMorest & Stull, Sudbury, as assistant under articles. While engaged here he contracted a severe cold, thus weakening him and leaving his system only a too fruitful ground for the fatal typhoid which followed. His death occurred at his home near the village of Glen Williams, in the county of Halton, where the friends of his boyhood and early manhood mourn for one who, in life, returned to them after his absences with a kindly and home-like interest in all, but who now has crossed to "that undiscovered country from whose bourne no traveller returns."

Mr. McGregor was reared in the county of Halton and received a public school training in the village school, followed by a course of several years in the Georgetown High School. Teaching in one of the public schools of his native county occupied his time for the next few years.

The autumn of 1902 marked the commencement of a new student career, for it found Mr. McGregor registered in the Civil Engineering course in the Faculty of Applied Science and Engineering. With all moderation it can be said that no student graduated in 1905 with a better grasp of the work as applied to the practical side of engineering than he who went forth from the well-known halls destined so soon to meet death.

The Scotch-Irish parentage of our dead friend produced at once a nature in which cool judgment blended with that sensitive Irish intuition. This same intuition and caution made him a good judge of men and things in all walks of life. Loyalty to his chosen friends, a rigid adherence to the principles of fair play, and a wide toleration of the faith and feelings of all, summarize his character and reveal at the same time a consistent follower of the Golden Rule.

N. H. KYLE.

On Feb. 5th of this year, death came almost without warning to Mr. N. H. Kyle, of Wiarton, one of the youngest members of the class of '08. Death was due ultimately to rheumatism of the heart, and his illness was of but six days' duration. Kyle was not a student of the loud or aggressive type. Quiet, industrious, kindly, he preferred his books and his work to the more strenuous activities of the campus. He was but sixteen years of age. Among his classmates, by whom he was regarded as a most estimable young man, and an unusually conscientious student, the occurrence of his untimely death is regarded as one of the saddest events of their experience.

TREASURER'S REPORT.

MR. PRESIDENT,—

I beg to submit the following statement showing balances, receipts, and expenditures for the term ending March 28th, 1906:—

To Balance on hand			$ 272 32
" amount of members' fees	$ 356 25		
" " life members' fees	23 00		
" " library proceeds	1,140 00		
" " from advertising	152 00		
" " of sale of pamphlet No. 18	1 00		
" " Government grant	75 00		
" " Receipts from annual dinner	484 00		
		$2,231 25	
Total			$2,503 57
By amount of publishing pamphlet No. 18		$ 401 06	
" " printing account (Dinner and Eng. Soc.)		135 72	
" " paper and supplies		775 45	
" " postage and stationery		22 28	
" " election expenses		29 10	
" " pins		10 25	
" commissions and discounts		15 85	
" customs and freight		6 95	
" expenses of representative to Queen's		20 00	
" expenses of representative to O. A. C.		10 00	
" Editor's salary		50 00	
" Assistant Librarian's salary		25 00	
" photos, etc.		12 00	

By present to Mr. James	$25 00
" postage on pamphlet No. 18	15 50
" amount of dinner expenses	463 85
	$2,018 01
By balance in Bank of Commerce	485 56
	$2,503 57

The stock and outstanding debts, etc., bring the balance to $1,246 31

All of which is respectfully submitted.

D. W. MARRS,
Treasurer.

AUDITORS' REPORT.

We, the undersigned, have this day examined the books of the Treasurer, D. W. Marrs, and find them correct.

K. A. MACKENZIE,
G. R. WORKMAN, } *Auditors.*

School of Practical Science,
Toronto, March 28, '06.

EXCHANGES.

Ontario Land Surveyors, Toronto, Report, 200 copies.
Michigan Engineering Society, Climax, Mich., Michigan Engineer, 135 copies.
Engineering Society, University of Illinois, Champaign, Ill., Technograph, 125 copies.
Association of Civil Engineers, Cornell University, Ithaca, N.Y., Transactions, 125 copies.
Engineering Society, University of Michigan, Ann Arbor, Michigan Technic, 125 copies.
Purdue Society of Civil Engineers, Lafayette, Ind., 100 copies.
Colorado School of Mines, Golden, Col., 100 copies.
University of Colorado, Boulder, Col., Journal of Engineering, 50 copies.
Ontario Association of Architects, Toronto, Ont., 40 copies.
University of Toronto Studies, Toronto, Ont.
Ontario Historical Society, Education Dept., Toronto, Ont.
Bureau of Mines, Toronto, Ont.
Geological Survey of Canada, Ottawa, Ont.
Queen's University, Kingston, Ont.
Canadian Society of Civil Engineers, Montreal, P.Q.
Canadian Mining Institute, Nova Scotia, Can.
Association of Engineering Societies, Philadelphia, Pa.
Pratt Institute, Brooklyn, N.Y.
Rensallaer Society of Engineers, Troy, N.Y.
Columbia University, New York, N.Y.
Indiana Engineering Society, Indianapolis, Ind.
American Society of Civil Engineers, New York, N.Y.
United States Coast and Geodetic Survey, Washington, D.C.
United States Tests of Metals, etc., Washington, D.C.
Patent Office, London, Eng.
Institution of Mechanical Engineers, London, Eng.
Royal Institution of British Architects, London, Eng.
Society of Chemical Industry, London, Eng.
Institution of Junior Engineers, London, Eng.
Institution of Engineers and Shipbuilders, Glasgow, Scotland.
Societé des Ingenieurs Civils de France, Paris, France.

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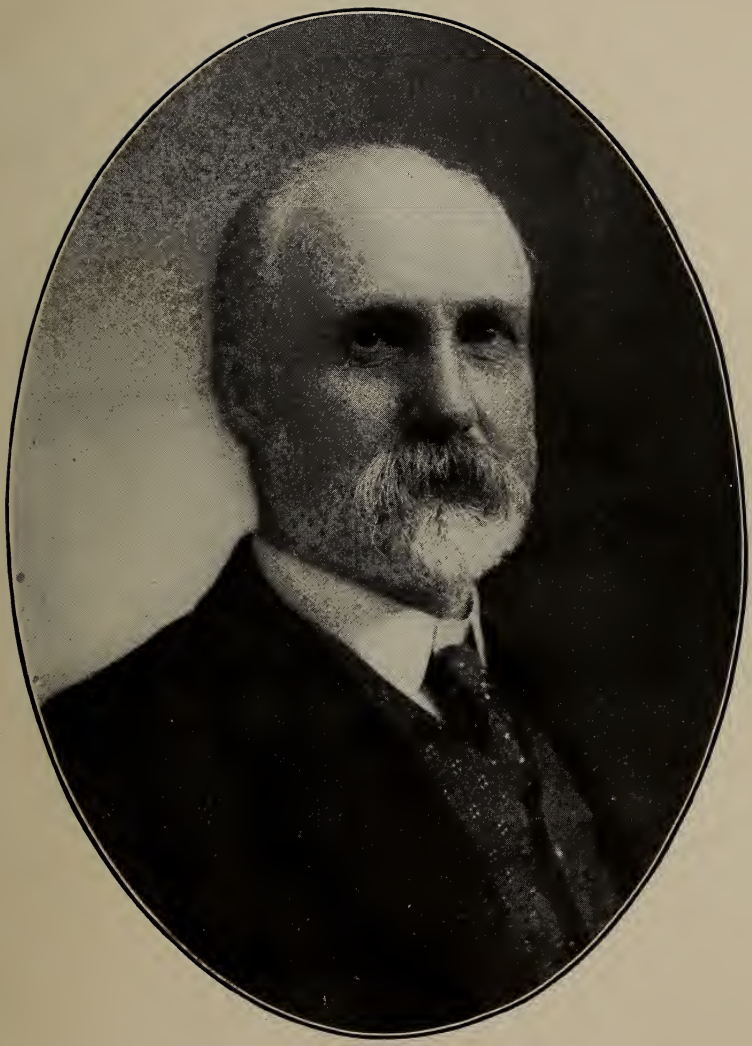

A. P. Coleman

No. 20. 1906-1907.

TRANSACTIONS

OF THE

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UNIVERSITY OF TORONTO

Price - 50 Cents.

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1907.

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PREFACE.

The twentieth volume of the Transactions of the Engineering Society of the Ontario School of Practical Science, now the Engineering Society of the University of Toronto, is offered to our readers as a record of part of the work accomplished by the Society during the session just closed.

A programme of the meetings of the year is printed elsewhere.

We take pleasure in presenting our readers with a portrait of Dr. A. P. Coleman, Professor of Geology, one of our honorary members.

The Society wishes to tender its thanks to all who contributed.

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Bruce, W. J., '07.
Bush, C. E., '07.
Campbell, G. A., '07.
Caster, J. H., '07.
Cavell, E., '07.
Chesnut, F. H., '07.
Clendening, A. C., '07.
Coleman, R. M., '07.
Connell, C. B. B., '07.
Cory, R. Y., '07.
Coulter, G. P., '07.
Cowper, G. C., '07.
Culbert, J. V., '07.
Davis, R., '07.
Dawson, G. A., '07.
Evans, S. D., '07.
Ewart, F. R., '07.
Fleming, G. R. S., '07.
Fux, P. C., '07.
Galletly, J. S., '07.
Galt, G., '07.
Garrow, A. B., '07.
Gillies, A., '07.
Graham, G. W., '07.
Grasett, C. S., '07.
Hagarty, R. E. W., '07.
Hall, K., '07.
Hamilton, C. T., '07.
Hara, F. J., '07.
Hare, R. A., '07.
Hertzberg, H. F. H., '07.
Hewson, E. G., '07.
Hill, H. O., '07.
Hogg, T. H., '07.
Hutton, C. H., '07.
Hyland, H. M., '07.
Hyman, E. W., '07.
Ireland, L. G., '07.
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Jackson, C. B., '07.
Kay, E. W., '07
Keith, D. F., '07.
Keith, H. P., '07.
Kinghorn, A. A., '07.
Klingner, L. W., '07.
Lamb, F. C., '07.
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Le Pan, A. D'Orr, '07.
Lindsay, J. H., '07.
McCurdy, J. A. D., '07.
McFarlane, J. B., '07.
McGugan, D. J., '07.
McIntosh, A. H., '07.
McNeill, F. W., '07.
McQuarrie, M. K., '07.
MacLeod, G., '07.
Mackay, A. G., '07.
Mackenzie, W. D., '07.
Malcolmson, W. S., '07.
Marshall, S. A., '07.
Mason, D. H. C., '07.
Maynard, H. V., '07.
Melson, J. W., '07.
Mills, G. G., '07.
Minns, J. B., '07.
Molesworth, G. N., '07.
Moore, J. M. C., '07.
Morley, P. F., '07.
Munro, D. G., '07.
Murray, E. W., '07.
Murray, J. D., '07.
Neelands, E. W., '07.
Neelands, R. E. K., '07.
Neilly, B., '07.
Nourse, A. E., '07.
O'Sullivan, J. J., '07.
Paton, T. K., '07.
Paulin, F. W., '07.
Percy, H. A., '07.
Potter, R. B., '07.
Procknow, F. E., '07.
Procunier, J. F., '07.
Quance, G. E., '07.
Raine, H., '07.
Rannie, J. L., '07.
Richardson, C. W. B., '07.
Ridler, A. A., '07.
Rothwell, H. E., '07.
Scholfield, C. A., '07.
Sheppard, A. C. T., '07.
Smith, F. R., '07.
Smithrim, E. R., '07.
Snaith, W., '07.
Southworth, H., '07.
Spencer, A. C., '07.
Stewart, G. S., '07.
Stiles, J. A., '07.
Stiver, J. L., '07.
Strathy, E. L. G., '07.
Stuart, J. L. G., '07.
Summers, G. F., '07.
Sutcliffe, H. W., '07.
Thompson, P. M., '07.
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Walker, W. J., '07.
Wilkes, E. D., '07.
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Woods, M. H., '07.
Wright, G. W. A., '07.
Young, J., '07.
Zimmer, A. R., '07.

Adams, O. F., '08.
Akers, H. G., '08.
Allan, L. F., '08.
Allison, C. B., '08.
Anderson, R. M., '08.
Annis, S. E., '08.
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Armstrong, H. V., '08.
Barber, H. C., '08.
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Beckstedt, R. D. S., '08.
Bedford, F. J., '08.

Beith, R. E., '08.
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Buchan, P. H., '08.
Cameron, D., '08.
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Carrie, K. N., '08.
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Cole, W. E., '08.
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Dahl, A. D., '08.
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Edwards, C., '08.
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Foord, R. J., '08.
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Francis, G. C., '08.
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Gear, S. S., '08.
Gemmel, H. W. R., '08.
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Grassie, A., '08.
Greene, W. H., '08.
Gulley, C. L., '08.
Hackner, J. W., '08.
Hall, R. H., '08.
Harris, F. K., '08.
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Henderson, C. D., '08.
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Huether, A. D., '08.
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Johnston, J. T., '08.
Keffer, A. H. E., '08.
Kennedy, H. G., '08.
Kennedy, M. D., '08.
Keys, W. R., '08.
Killip, W. C., '08.
King, W. S., '08.
Kortright, F. H., '08.
Lawrence, J. B., '08.
Leslie, J. N. M., '08.
Lewis, F. C., '08.
Lynar, H. R., '08.
McCracken, J. F., '08.
McDonald, M. P., '08.
McGeorge, W. G., '08.
McKechnie, F. H., '08.
McKnight, J. H., '08.
McLeod, G., '08.
McMaster, W. A. A., '08.
McMordie, H. C., '08.
McRoberts, A. A., '08.
Madge, N. G., '08.
Maguire, H. C., '08.
Malone, J. E., '08.
Marlatt, K. D., '08.
Marshall, R. J., '08.
Meader, C. H., '08.
Milligan, G. L., '08.
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Molesworth, J. C. P., '08.
Monk, E. D., '08.
Moody, F. H., '08.
Morice, J. H., '08.
Mowbray, F. E. H., '08.
Murray, S., '08.
Murray, W. P., '08.
Nasmith, M. E., '08.
O'Donnell, V. J., '08.
O'Grady, W. de C., '08.
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Pae, A. W., '08.
Peckover, H. J., '08.
Pequegnat, M., '08.
Phillips, F. F., '08.
Pigott, R. B., '08.
Pivnick, M., '08.
Ponton, G. M., '08.
Power, C. W., '08.
Proctor, I., '08.
Proctor, E. M., '08.
Publow, C. F., '08.
Qua, A. H., '08.
Ransom, J. T., '08.
Redfern, W. B., '08.
Reesor, N. H., '08.
Richardson, F. L., '08.
Ricker, H. A., '08.
Robertson, F. A., '08.
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Robinson, R. C., '08.
Robinson, W. A., '08.
Rogers, L. J., '08.
Rose, R. R., '08.
Ross, D., '08.
Sanderson, A. U., '08.
Secord, A. O., '08.
Shaw, W. E. V., '08.
Shearer, H. F., '08.
Spence, J. J., '08.
Squire, G. E., '08.
St. Lawrence, J., '08.
Stamford, W. L., '08.
Starr, R. H., '08.
Stayner, D. S., '08.

Stewart, A. W. J., '08.
Stock, J. J., '08.
Stuart, H. B., '08.
Sword, A. D., '08.
Taylor, W. E., '08.
Taylor, J. W. R., '08.
Thomas, V. C., '08.
Thompson, H. P., '08.
Thornley, H., '08.
Toms, C. G., '08.
Underwood, J. E., '08.
Van Norman, C. P., '08.
VanNostrand, J., '08.
Villeneuve, T. L., '08.
Walker, J. A., '08.
Waugh, B., '08.
Webb, C. E., '08.
Webster, W. J. C., '08.
Wedlake, R. M., '08.
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West, A. M., '08.
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Wing, D. O., '08.
Workman, G. R., '08.
Young, R., '08.

Agnew, J. N., '09.
Alison, A. E., '09.
Allen, E. R., '09.
Amsden, W. G., '09.
Anderson, A. L., '09.
Arens, E. G., '09.
Austin, E. T., '09.
Baird, J. A., '08.
Barnett, H. A., '09.
Barry, W. H., '09.
Bennett, A., '09.
Berry, B. C., '09.
Birchard, E. R., '09.
Black, W. D., '09.
Blair, F. J., '09.
Blizard, C., '09.
Boland, T. M., '09.
Boulton, W. J., '09.
Bowen, G. H., '09.
Browne, E., '09.
Brydon, A. R., '09.
Buchanan, J. A., '09.
Burns, J., '09.
Calvert, D. G., '09.
Cameron, M. G., '09.
Campbell, A. D., '09.
Campbell, R. A., '09.
Carlyle, W. M., '09.
Cawley, H. E., '09.
Cepeda, M., '09.
Chesnut, V. S., '09.
Clarke, F. W., '09.
Cline, C. G., '09.
Cockburn, R. B., '09.
Collinson, W. G., '09.
Collinson, J. G., '09.
Coltham, G. W., '09.
Cooch, H. A., '09.
Corman, W. E., '09.
Crosby, T. H., '09.
Cumming, N. S., '09.
Cunerty, T. J., '09.
Cunningham, R. H., '09.
Dallyn, F. A., '09.
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Davis, H. W., '09.
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Dawson, I. H., '09.
Derham, W. P., '09.
Dissette, A. C., '09.
Dodds, W. A., '09.
Douglas, W. H., '09.
Duff, A. R., '09.
Duthie, H. B., '09.
Duthie, L. J., '09.
Ellis, H. C, '09.
Evans, W. G., '09.
Falconer, F. S., '09.
Farrell, K. A., '09.
Ferguson, J. B., '09.
Fergusson, A. P., '09.
Fetherstonhaugh, J. E., '09.
Fisken, J. B. K., '09.
Fletcher, F. T., '09.
Flynn, C. C., '09.
Fortier, L. H., '09.
Fraser, A., '09.
Fraser, W. J., '09.
Freeborn, S. G., '09.
Freeman, T. E., '09.
Frost, E. R., '09.
Furgey, T. A., '09.
Fyfe, H. D., '09.
Gibson, E. P., '09.
Gibson, C. A., '09.
Gibson, M. M., '09.
Glazier, M. B., '09.
Goad, V. A. E., '09.
Goggin, V. T., 09.
Gooderham, A. E., '09.
Goodeve, V., '09.
Gooding, H. C., '09.
Gordon, O. D., '09.
Gorrie, D. A., '09.
Gourlay, V. F., '09.
Graham, D. A., '09.
Grant, R. R., '09.
Grant, A. D., '09.
Gray, J. E., '09.
Greene, R. L., '09.
Greene, G. E. D., '09.
Greey, A., '09.
Griffith, T. G., '09.
Gunn, W. W., '09.
Gzowski, J. S., '09.
Hagerman, F. G., '09.
Hall, H., '09.
Hall, R. S., '09.
Harcourt, R. M., '09.
Harper, C. J., '09.
Harstone, R. G. L., '09.
Hartney, H. E., '09.

Harvey, D. W., '09.
Hatch, F. C., '09.
Hay, C. O., '09.
Heintzman, H., '09.
Helliwell, J. G., '09.
Hemphill, J., '09.
Henderson, E. Mc., '09.
Hicks, N. W., '09.
Hill, A., '09.
Hinch, E. F., '09.
Hollingshead, G., '09.
Holmes, A. E., '09.
Holmes, C., '09.
Holton, G. H., '09.,
Hoshal, G. C., '09.
Huffman, K., '09.
Hughes, C., '09.
Hunter, A. E., '09.
Hyland, R. T., '09.
Irwin, A. B., '09.
Irwin, H., '09.
Isbister, J., '09.
Jack, R. T. G., '09.
Jackes, F. P., '09.
Jackson, J. E., '09.
James, E. W., '09.
James, G. A., '09.
Jamieson, E. A., '09.
Jardine, G. R., '09.
Jeffery, C. C., '09.
Jelfs, F. C., '09.
Jennings, R. B., '09.
Johnson, C. C., '09.
Johnston, W. J., '09.
Kean, D. J., '09.
Kemp, J. B. O., '09.
Kennedy, W. J. MacK.
Kettle, T. H., '09.
Key, W. R., '09.
Klotz, H. N., '09.
Lamont, A. W., '09.
Langmuir, B., '09.
Leadman, H. L., '09.
Lee, F. A., '09.
Leitch, J. N., '09.
Lennox, A. E., '09.
Loucks, R. W. E., '09.
McAlpine, D. D., '09.
McArthur, A. S., '09.
McClenahan, C. A., '09.
McColl, E. B., '09.
McCollum, C. R., '09.
McConnell, W. A., '09.
McCool, A. J., '09.
McCordick, A. S., '09.
McCuaig, P. J., '09.
McDonald, G. G., '09.
McDonald, G. E., '09.
McDougal, J. E., '09.
McDougall, S. G., '09.
McEachren, F. P. Y., '09.
McElhanney, T. A., '09.
McIntosh, W. G., '09.
McMillan, V., '09.
McSloy, J. I., '09.
McVean, R., '09.
MacAndrew, W. M., '09.
MacKinnon, J. G., '09.
MacLachlan, W. A., '09.
MacLean, J., '09.
Macdonald, J. B., '09.
Macfarlane, E. D., '09.
Mackintosh, N. H., '09.
Macpherson, N. W., '09.
MacPherson, G. A., '09.
Manning, N. H., '09.
Manson, A. B., '09.
Markle, G. A., '09.
Marshall, H. J., '09.
Martindale, E. S., '09.
Martyn, O. W., '09.
Michaud, J. A., '09.
Middleton, J. J., '09.
Miller, W. N., '09.
Mills, P. E., '09.
Morgan, J. P., '09.
Morris, C. A., '09.
Morton, G., '09.
Muldrew, W. H., '09.
Munro, F. V., '09.
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Murton, J. C., '09.
Nash, J. C., '09.
Nelles, J. S., '09.
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New, R. H., '09.
Newton, W. E., '09.
Niebel, E. H., '09.
Odell, L. S., '09.
O'Flynn, J. D., '09.
O'Gorman, C. A. W., '09.
O'Neil, C. M., '09.
Palmer, E. P. B., '09.
Parish, A. G., '09.
Patterson, E. B., '09.
Peters, F. M., '09.
Petry, A. McN., '09.
Philp, W. M., '09.
Pollard, S. B., '09.
Porter, L. A., '09.
Porter, C. J., '09.
Pounder, I. R., '09.
Pye, D. E., '09.
Quail, J., '09.
Railton, L. W., '09.
Ramsperger, A. F., '09.
Redfern, C. R., '09.
Rogers, R. G., '09.
Rose, G. B., '09.
Rubidge, W. F. B., '09.
Rudolf, O. R., '09.
Rudy, I. S., '09.
Rust, F. C., '09.
Rutledge, L. T., '09.
Ryerson, J. E. E., '09.
Sara, R. A., '09.
Schlarbaum, A., '09.
Schwenger, C. E., '09.
Sedgwick, A., '09.
Segré, B. H., '09.
Self, J. H., '09.
Sharpe, D. N., '09.
Shaw, M. R., '09.
Shirriff, C. M., '05.
Smith, E. A., '09.
Smith, F. L., '09.
Sparling, M. W., '09.
Spinney, E. H., '09.

ORDINARY MEMBERS—CONTINUED

Stewart, N. C., '09.
Stewart, J. D., '09.
Street, J. C., '09.
Stroud, S., '09.
Stutt, H. G., '09.
Sutherland, C. C., '09.
Sutherland, D., '09.
Sylvester, K. B., '09.
Swan, R. G., '09.
Tate, H. W., '09.
Thompson, E. A., '09.
Thompson, G. G., '09.
Tipper, G. A., '09.
Train, C. W., '09.
Trees, A. G., '09.
Trusler, W. A., '09.
Turnbull, W. G., '09.
Van Allen, M., '09.
Vatcher, A., '09.
Venney, L. T., '09.
Vogan, S. J., '09.
Waite, C. B., '09.
Walker, C. M., '09.
Walker, J. T., '09.
Wallace, J. L., '09.
Warrington, G. A., '09.
Watson, C. E., '09.
Webb, E. E, '09.
White, F. C., '09.
Whitelaw, A. R., '09.
Wilkinson, R. G., '09.
Williams, J. A. McK., '09.
Williamson, O. T. G., '09.
Wilson, E. R., '09.
Wilson, H. P., '09.
Wilson, L. Z., '09.
Wilson, R. R., '09.
Woodley, G. E., '09.
Wookey, S. A., '09.

T. KENNARD THOMSON, C. E.

A BIOGRAPHY OF WHOM APPEARS ELSEWHERE.

A. P. COLEMAN, M.A., Ph.D.

Arthur Philemon Coleman was born in the village of Lachute, in the Province of Quebec, on the 4th of April, 1852. His father was the Reverend Francis Coleman, a native of England, and a well-known and highly esteemed minister of the Methodist Church. His mother, Emmeline Maria Adams, was a descendant of the U. E. L. branch of the Adams family who had settled in New England in the seventeenth century. Her sister, Miss Mary E. Adams, was widely known as an eminent educator, and a woman of rare intellectual and artistic gifts; and after Mrs. Coleman's early death she extended a mother's affectionate care to her sister's orphaned children.

Mr. Coleman received his preparatory training in the public and high schools of Ontario, and after a brief apprenticeship as a teacher in a public school, he entered Victoria College as an undergraduate of the first year in the autumn of 1872. At matriculation he won the Mark Bursary, and at the end of the year the first place in Classics with the Mills Prize, and the Wallbridge Prize in Greek Testament. At the end of the second year he won the first place in the examination for the Biggar Scholarship, covering English, Classics, and Natural Science, and next the Webster Prize in English Composition at the end of the third year. At graduation he was bracketed with Mr. James Smith, for the Prince of Wales Gold Medal, the highest honor of the year—his subjects being Classics, Physics, Science and French. Immediately after graduation he was appointed Classical Master in the Cobourg Collegiate Institute. He also commenced a course of post-graduate studies in Science in the laboratory of Faraday Hall, under Dr. Haanel, now the Dominion Superintendent of Mines, and secured the M.A. degree in 1880. He next proceeded to Germany and con-

tinued his scientific studies in the University of Breslau, where he received the degree of Ph.D., *cum laude,* in 1882. His major subject was Geology, his dissertation was on "The Melaphyrs of Lower Silesia," and his minors were Mineralogy and Chemistry. Ten years later he again visited Germany and spent a year in the study of Metallurgy in the famous School of Mines at Freiberg. While in Europe his vacations were spent in field work in Bohemia, Switzerland and Scandinavia.

On his return to Canada he received the appointment of Professor of Geology and Natural History in Victoria University, which he held till 1891, when, after the federation of Victoria with the University of Toronto, he was transferred to the staff of Applied Science and Engineering in the Provincial University, and on the resignation of Prof. Chapman was appointed professor of Geology in the faculty of Arts. Since his appointment the work has grown until it now occupies the full time of two professors, an associate professor and two assistants, with a Curator of the Museum.

Dr. Coleman is distinguished not only for his extensive scientific attainments, but also for his rare literary gifts, and is exceedingly popular as a writer and public lecturer on scientific subjects. His field work in Geology has covered the whole region of New Ontario east and west, and the Rocky Mountains from the boundary line to the Yukon. As he is still in the prime of life the University may hope from him for many years valuable service.

PROGRAMME OF REGULAR MEETINGS, 1906-7.

October 10th, 1906—

Prof. Coleman, "Geological Trip through Mexico."

Mr. E. L. Cousins, '06, "Irrigation in Alberta."

Mr. J. M. Wilson, '07, "City Water Tunnel."

October 24th, 1906—

Mr. P. Gillespie, "Water Power Development at Niagara Falls."

November 8th, 1906—

Debate on "Type of Construction for Panama Canal."

Messrs. Near, '06; Lepan,'07; McGugan, '07; Challen, '08; Brecken, '08, and Vogan, '09.

November 22nd, 1906—

Prof. Rosebrugh, "Engineering Ethics."

Mr. W. McLaughlin, '06, "Shop Work for Mechanical and Electrical Engineers."

Mr. M. P. Death, '06, "Repairing Dynamos and Motors."

Mr. T. H. Hogg, '07, "Coffer Dams for Ontario Power Co., at Niagara Falls."

December 6th, 1906.

Mr. S. Gagné, "Advice to Young Engineers."

January 17th, 1907—

Mr. T. H. Hogg, "Electric Power Transmission."

January 30th, 1907—

Mr. Vickers, '06, "Steam Turbines."

Mr. W. F. Scott, "Engineering Features in Connection with Royal Alexandra Theatre."

February 14th, 1907—

Mr. C. H. Mitchell, "Hydro-Electric Development in Europe."

February 22nd, 1907—

Special meeting for consideration of new constitution.

February 27th, 1907—

New constitution amended and adopted.

Mr. T. Kennard Thomson, "Pneumatic Caissons."

March 6th, 1907—

Special meeting.

Mr. Reg. Hagarty, '07, "Railroad Terminals."

March 13th, 1907—

Nominations.

March 19th, 1907—

Mr. John M. Ewen, "Modern Building Construction from Standpoint of Engineer-Constructor."

March 27th, 1907—

Mr. S. Dushman, "Electric Metallurgy of Iron and Steel."

Mr. F. R. Smith, "Georgian Bay Canal."

EXCHANGES.

Ontario Land Surveyors, Toronto, Report, 200 copies.
Michigan Engineering Society, Climax, Mich., Michigan Engineer, 135 copies.
Engineering Society, University of Illinois, Champaign, Ill., Technograph, 125 copies.
Association of Civil Engineers, Cornell University, Ithaca, N.Y., Transactions, 125 copies.
Engineering Society, University of Michigan, Ann Arbor, Michigan Technic, 150 copies.
Purdue Society of Civil Engineers, Lafayette, Ind., 100 copies.
Colorado School of Mines, Golden, Col., 100 copies.
University of Colorado, Boulder, Col., Journal of Engineering, 60 copies.
Ontario Association of Architects, Toronto, Ont., 40 copies.
University of Toronto Studies, Toronto, Ont.
Ontario Historical Society, Education Dept., Toronto, Ont.
Bureau of Mines, Toronto, Ont.
Geological Survey of Canada, Ottawa, Ont.
Queen's University, Kingston, Ont.
Canadian Society of Civil Engineers, Montreal, P.Q.
Canadian Mining Institute, Nova Scotia, Can.
Association of Engineering Societies, Philadelphia, Pa.
Pratt Institute, Brooklyn, N.Y.
Rensallaer Society of Engineers, Troy, N.Y.
Columbia University, New York, N.Y.
Indiana Engineering Society, Indianapolis, Ind.
American Society of Civil Engineers, New York, N.Y.
United States Coast and Geodetic Survey, Washington, D.C.
United States Tests of Metals, etc., Washington, D.C.
Patent Office, London, Eng.
Institution of Mechanical Engineers, London, Eng.
Royal Institution of British Architects, London, Eng.
Society of Chemical Industry, London, Eng.
Institution of Junior Engineers, London, Eng.
Institution of Engineers and Shipbuilders, Glasgow, Scotland.
Societé des Ingenieurs Civils de France, Paris, France.

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ENGINEERING SOCIETY

OF

The University of Toronto

TORONTO.

PRESIDENT'S VALEDICTORY.

GENTLEMEN:—

This is the last time I shall have the opportunity of addressing you as your President. It gives me the greatest pleasure to thank you for your hearty co-operation throughout my term of office. It is gratifying to think that the same enthusiasm which is so characteristic of the "School" in athletics has been carried into our Society, and that the attendance at our meetings has been limited only by the accommodation available (300 seats).

All our college functions and enterprises have been uniformly successful, have more than kept pace with the phenomenal growth of the Faculty of Applied Science.

The business of the Society has grown to such magnitude and has become so complex that it is almost impossible for the chief executive officers of the Society to do justice to their academic work, and at the same time properly carry out the duties of their offices. No man should accept any office who will not give his very best efforts to the same. For this reason, and also to endeavor to secure better results in the matter of discussion of papers, the Society has

been sub-divided. This will permit of the discussion of papers of peculiar interest to the several departments. It is to be hoped that the arrangement will work out so as to secure more elasticity without impairing the strength of the Engineering Society..

You have approved of the idea of having a permanent Secretary, who will devote most of his time to the interests of the student body. It is more than probable that before you assemble in the fall, the details will be worked out and an appointment made.

The business of the Society has exceeded that of any previous year. Your committee, however, concluded that it was not good policy to continue piling up a surplus. A considerable reduction in the price of supplies was consequently made. With the appointment of a Secretary the Society will be able to go more extensively into the sale of supplies, and a further cut may be confidently expected.

The relations between the student body and the staff have been most cordial. The only real grievance in existence is the overcrowded condition of the buildings. More space for drafting and more laboratory accommodation for engineering work proper, are urgently required. It is anticipated that the Board of Governors of the University will take immediate action in the matter.

Much has been accomplished this year. Credit should go where it belongs. Too much approbation cannot be given to the most loyal and able executive committee with whom it has been my lot to work. It is very rarely a president is fortunate enough to have such a reliable committee, and to them most of the credit belongs.

In conclusion let me thank you for the honor you have done me—an honor which I have always striven to merit.

I have much pleasure in presenting to the Society their President-elect for 1907-'08, Mr. T. H. Hogg.

Yours sincerely,

KEN. A. MACKENZIE.

T. KENNARD THOMSON.

T. Kennard Thomson, '86, was born in Buffalo in 1864. He is the son of the late Wm. Alex. Thomson, founder of the Canada Southern R. R., who, at the time of his demise in 1878, represented the County of Welland in the Canadian House of Commons.

It was while a second year student at the School of Practical Science that Mr. Thomson first conceived the idea of founding an Engineering Society. The consensus of opinion among the students at that time seemed to be that the student body was too weak numerically to attempt such an undertaking. Thomson, however, thought otherwise. Some time during that year he invited the second and third year classes, Professor Galbraith, Doctor Ellis and a few outside friends, to take supper with him, and there took advantage of the opportunity to suggest the starting of an Engineering Society. All present enthusiastically indorsed the scheme, and a committee was appointed on the spot to draft a constitution. About the same time, Mr. H. J. Bowman, '85, had introduced an engineering display at the annual conversazione. The two joined forces and the Engineering Society of the School of Practical Science was launched on its career.

It is a source of gratification to older graduates, among them Mr. Thomson, that the Society has, for twenty-two years, continued to extend its sphere of usefulness. It has never halted in its march, and the outlook at the present time is brighter than ever before.

The three summers prior to graduation Thomson spent on the Canadian Pacific in the Rocky Mountains, and the two years immediately after graduation, with the Dominion Bridge Co. of Montreal. He then considered that he could do better in the States and went to New York on "spec." After four days spent in looking around the great metropolis, he met the Chief Engineer of the Pencoyd Bridge Co., and engaged with him to enter the employ of this

corporation at Pencoyd, Pa. This position he retained until the following spring (1889), when he resigned in order to visit the Paris Exhibition with the American Society of Civil Engineers. He remained abroad four months and after his return was re-engaged by his old employers at a substantial advance in salary. This position he held until his former chief on the C. P. R. offered him the position of Bridge Engineer on the Ohio extension of the Norfolk and Western Railway. This involved the design and erection of one hundred and twenty-nine bridges, including the big one over the Ohio River at Kenova, West Virginia.

In 1891 he accepted a position as Superintendent of Bridges for Mr. Chas. M. Jacobs, Consulting Engineer, for whom he rebuilt several bridges and reported on many others. Following this, he was engaged by the Yale and Torone Mfg. Co. of Stamford, Conn., for about a year, during which time he made a series of standard designs for electric travelling cranes, etc.

Thomson then became Chief Engineer of a highway bridge company, and after its failure became Principal Assistant Engineer to his old chief, Mr. Jacobs, his special charge being the proposed Blackwell's Island Bridge. After two piers had been completed to above high water and the plans for 80,000,000 pounds of bridge steel had been approved, matters came to a standstill owing partly to stringency in the money market and partly to the death of Mr. Austin Corbin, President of the Long Island Railroad, for whom the bridge was being constructed. The work has never been resumed. Mr. Thomson was then engaged by Arthur McMullen & Co., a large firm of foundation contractors, to make the plans for and supervise the construction of the Commercial Cable foundations on Broad Street, New York City. This marks the beginning of deep cellar foundation construction in New York. The foundations were carried about 30 feet below water in this instance, and the cellar floor was placed 16 feet below water.

He was Engineer for this firm for about eight years, during which time they constructed the Mutual Life Building, foundations

with a cellar thirty-two feet below water, some of the column foundations being carried 100 feet below the street, or 85 feet below water; the addition to the Manhattan Life, etc., etc.; the big stone ten-span arch bridge, eighty feet wide and twelve hundred feet long, at Hartford, Conn.; the caissons for the Monongahela Bridge at Pittsburg; Mingo Junction Bridge, Ohio; the Havre de Grace Bridge and many others.

About 1893 Mr. Thomson started doing work as a Consulting Engineer, and most of his salaried engagements since that time have permitted him to continue his private practice. He has made designs for coaling stations, elevated stations, bridges of all kinds, cable ways, train sheds, pneumatic canal locks, underground railroads and all kinds of contractors' plants. He has designed many pneumatic caissons and has been in the air chamber over two thousand times. He has been retained in the consulting capacity on over a dozen New York sky scrapers; has acted as arbitrator in law suits and has been in the expert witness chair on many occasions. He has taken out several tunnel, lighthouse and other patents.

Mr. Thomson married the third daughter of the late Mr. Arthur Harvey, F.R.S., of Toronto, and is the proud possessor of two daughters and three sons. He has been a frequent contributor to our "Papers," as well as to the current technical press. He is a member of the American Society of Civil Engineers, the Canadian Society of Civil Engineers, the Engineers' Club of New York, the National Geographical Society of Washington, the American Forestry Association, the Upper Canada College Old Boys' Association, and a life member of the Niagara Historical Society. He is also, this year, President of the Toronto University Club of New York, and last, but we trust not least, a life member of the Engineering Society of the School of Science, in which he has always felt and manifested a real paternal interest.

SOME NOTES ON PNEUMATIC CAISSONS FOR BRIDGES AND BUILDINGS.

T. Kennard Thomson, '86.

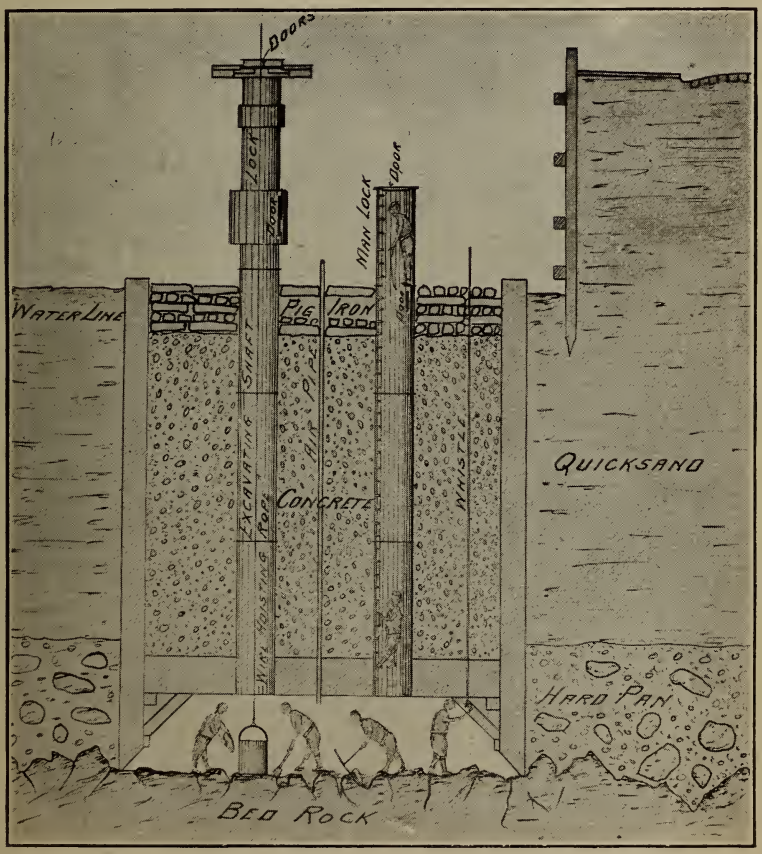
The best foundation for a bridge or building is of course bed rock, and it is almost the only foundation which does not permit of more or less settlement. Where there is no water to contend with, all that is necessary is to "shore" at the sides sufficiently to prevent caving in, while the material above rock is being excavated. But when water is encountered and the rock is not too far down, the material can be excavated by the open cofferdam method, which means driving sheeting down all around the excavation and continually pumping the water out.

The old method was to drive two-inch or three-inch planks ten or twelve feet long. When the excavation was completed to the bottom, a second set was driven inside the first. This was continued to the depth desired, but was in treacherous soil a very poor arrangement and the sides were almost invariably forced into the excavation, making the opening much smaller than desired.

The more modern sheeting consists of timbers up to 12″ wide with two strips nailed on one side and one strip on the other, forming a sort of tongue and groove arrangement. These are driven with a pile driver so that the points reach bed rock. In case the excavation does not go to rock, they are driven two or three feet below the level to which it is intended to excavate. By this means the water can be kept down by pumping, there being very little if any leakage through the sides. The material excavated will be in a tolerably dry state to a depth of about 30 feet below water, which

is pretty near the limit in bad material. An attempt to go much below this necessitates an enormous amount of bracing, etc., to keep the sides from collapsing.

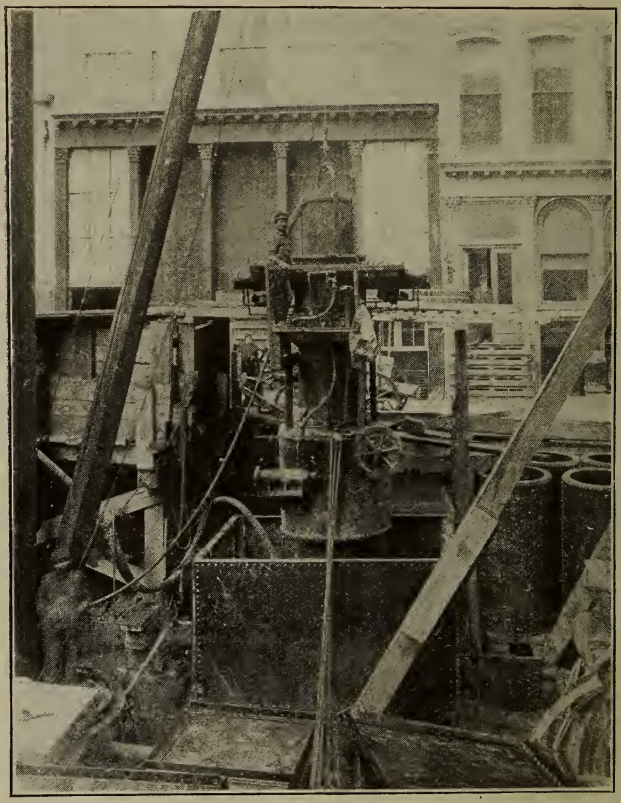
It is a question of dollars and cents in each case, whether it is better to use timber sheeting or one of the many forms of steel



A TYPICAL CAISSON.—SOMETIMES THE CAISSON IS CARRIED THROUGH HARD PAN AS SHOWN, BUT MORE OFTEN THE CUTTING EDGE STOPS AT HARD PAN AND THE EXCAVATION ONLY IS CARRIED DOWN

piling. For bridge work, when the rock is at greater depths; and for buildings in cities, where the rock may be at less depths, it is necessary to use the pneumatic caisson for economy and safety.

A pneumatic caisson is built in the shape of a box having four sides and a top or roof but no bottom. This box is made the exact size of that part of the pier which is to rest on the rock. In the roof are one or more openings for shafts, generally three feet in diameter, for removing material and allowing men to enter the box



MUTUAL LIFE BUILDING, '00-'01.—BUCKET ENTERING LOCK.

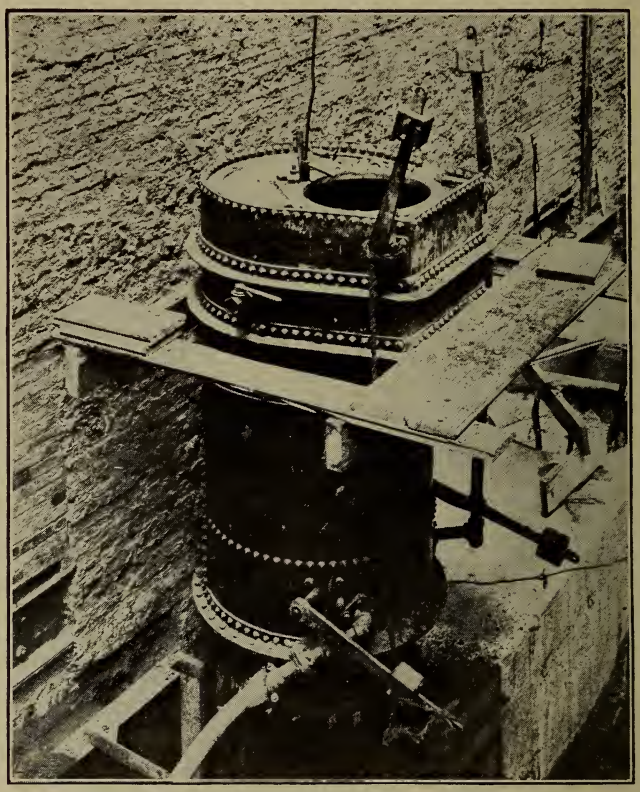
or air chamber. On top of the box is placed concrete to form a part of the permanent pier, and at the same time to furnish weight to overcome the friction of the earth on the sides and the air pressure in the air chamber. The amount of air pressure being governed by the depth of water, should be just sufficient to keep the

water out of the air chamber. As each cubic foot of water weighs $62\frac{1}{2}$ pounds, the pressure per square foot is $62\frac{1}{2}$ pounds for each vertical foot of water to be resisted, which is equivalent to .434 pounds per square inch. For a depth of 100 feet of water, this is $43\frac{1}{2}$ pounds per square inch above atmosphere, which is about the limit of human endurance. The first pneumatic caissons in this country were used in 1852 for a bridge over the Harlem River, New York City, where a number of cast iron cylinders were sunk to support the piers for a draw bridge. In this case a French expert was engaged at a big fee per diem, to come over and explain the process. The story has it that the contractors quickly learned all he had to teach and let him go after a week or so.

In all the early caissons, the air lock was placed in the air chamber, whereas it is now (except on very small caissons, say 3′ diam.) always placed on top of the shaft above the permanent work. For many years the hoisting apparatus was placed in the lock or shaft so that it was necessary to draw the material up into the lock from the air chamber, to shut the bottom door, and then hoist the material out of the lock. Now, there is a hole or slot in the upper door of the lock which permits the hoisting rope, a wire cable, to remain attached to the bucket during the entire ascent or descent, a very important point when the speed of the work depends on the number of trips the bucket (one-half a cubic yard capacity generally) can make an hour. I have frequently seen the bucket make 20 trips an hour. Wherever possible, it is much cheaper and quicker to "blow" the material out rather than shovel it into buckets to be hoisted out. This is done by means of a 4-or 5-inch iron pipe carried down through the concrete to the deck, where a short flexible pipe with proper valves is attached.

The sand hogs (caisson men) shovel the sand, clay, etc., around the bottom of the flexible pipe; then the valve is opened and the compressed air in the caisson immediately "blows" all the loose material through the pipe and the valve has to be shut while more material is shoveled. Some very rapid excavation has been done this way, especially in some of the East River caissons. It re-

quires about 10 pounds of air pressure in the caisson to blow successfully, and in river work the water is often 20 or more feet deep before the excavation starts. At the top of the blow pipe, it is generally necessary to have an elbow so that material can be discharged into the river or into scows. The force of the sand, small



A CAISSON LOCK.

KINDNESS OF LOUIS L. BROWN, '95. THE FOUNDATION COMPANY, N.Y.

stones, etc., is so terrific that an iron elbow 2 ins. thick is often worn through in a few hours. Especially hard metal is therefore indispensable.

Frequently, especially in city work, the amount of concrete to be placed in the cofferdam on top of the air chamber is not suffi-

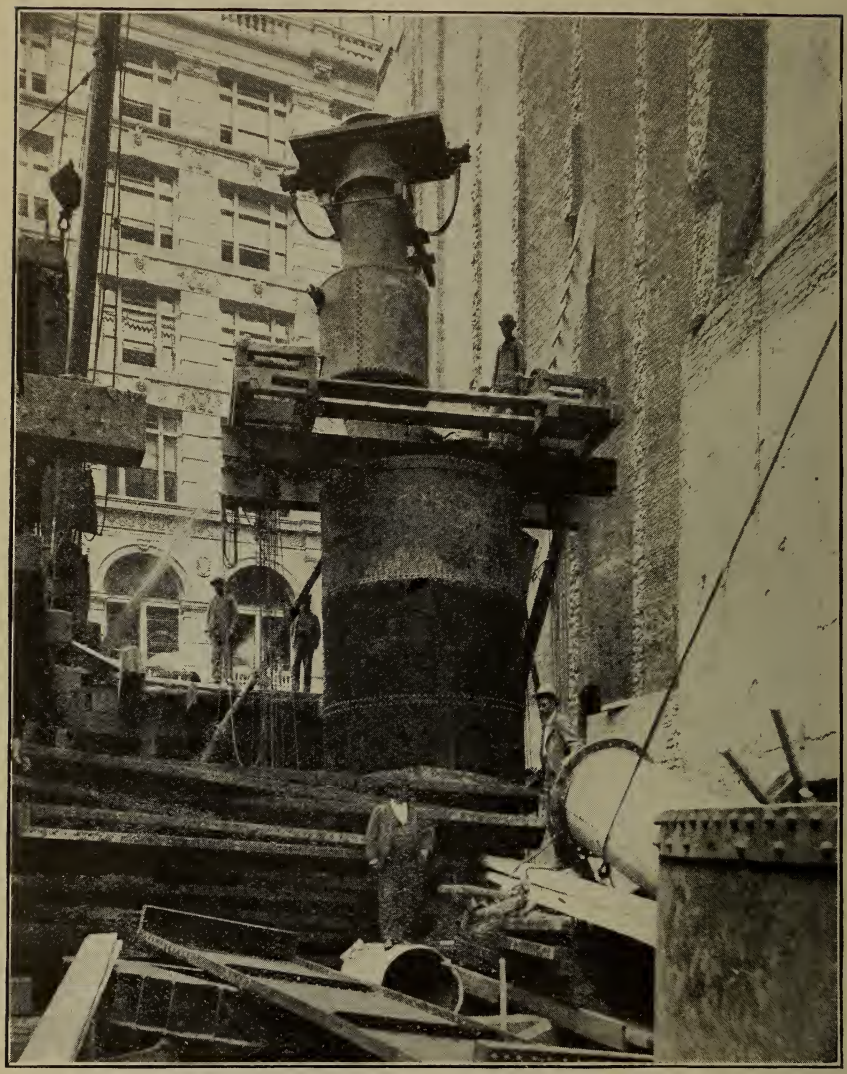
cient to overcome the air pressure and the friction, which varies from 50 to 650 pounds per square foot of contact surface. In such a case, the air pressure is reduced a few pounds and sometimes even to a pound or two (where it is safe to do so) for a few seconds, to allow the caisson to sink a foot or two into the excavation already made below the cutting edge. On some jobs, it is entirely too dangerous to reduce the pressure (called "blowing") in this way, and it is very necessary to add more weight, such as pig iron, cast iron blocks, etc., to make the caisson penetrate to the proper depth. Hundreds of tons additional weight are often required.

Caissons were first built of wood—now they are built of wood, steel, or concrete, according to the judgment of the engineer. The Mutual Life caisson is a good example of a steel caisson, and that of the East River Bridge, a recent example of how not to do it in wood.

COFFERDAMS.

In early days it was customary to start stone or brick piers directly on top of the caisson without use of cofferdams. This proved a mistake. In the first place, it did not allow of the weight being adjusted as required, to overcome the resistance, for in that case the masonry always had to be kept above water. I have often seen cases where the top of the concrete in the cofferdam was 20 feet or more below the surface of the water. It is just as dangerous to have a caisson too heavy as to have it too light. In the second place, I have known the friction of the earth, etc., to be sufficient to tear open the joints in the fresh stone or brick masonry. Even with good up-to-date Portland cement concrete, where there are no joints except at the deck, the caisson has been known to separate from the concrete above.

Most caisson men in their early days fall into the error of wanting to make the caisson bigger at the bottom than at the top, thinking to reduce the friction thereby. On the contrary, the reverse is the result, for as a rule the material falls into the space left above the cutting edge, and binds the caisson much more tightly than would



COMMERCIAL CABLE BUILDING.—LOCK BEING LIFTED ON.

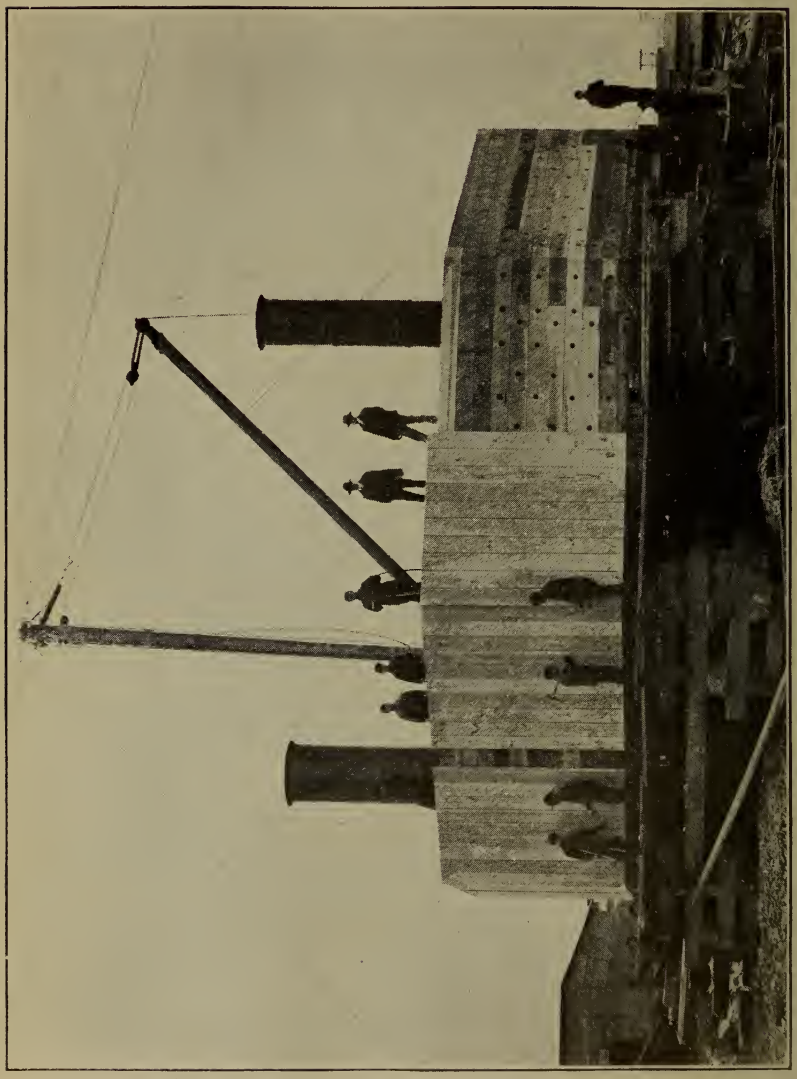
the regular friction. In sinking the Hawkesbury bridge in Australia, however, an unusual thing happened. The surrounding material did not fall against the sides of the cylindrical caissons, so that there was practically no friction. This being so, it was found impossible to guide the caisson to keep it in place and plumb. The contractors stopped sinking, packed new material all around the caisson and let it stand about a year before they started in again. This shows the bad results, both ways, of tapering a caisson.

When the site is covered with water, there are three ways of getting the caisson into position:—

First, to build the caisson on shore and skid it on runways into the water.

Second, to build it on a floating pontoon made of 2 or more sections bolted together. In this way the caisson is usually built with 4 or 5 feet of cofferdam attached. When all is ready, the bolts are taken out of the centre joint of the pontoon, dividing it into two sections. Stone or other weights having been placed near the centre, the water is permitted to enter, allowing the caisson to sink, until it draws about 8 or 10 feet of water. Sometimes in sinking, the extra weight under the centre of the caisson is sufficient to force the pontoon from under the caisson. Struts are sometimes attached to force the pontoon from under, and frequently tugs are used to pull the sections apart. The caisson is ready to be towed into position and to have more cofferdam added before concreting and sinking commences.

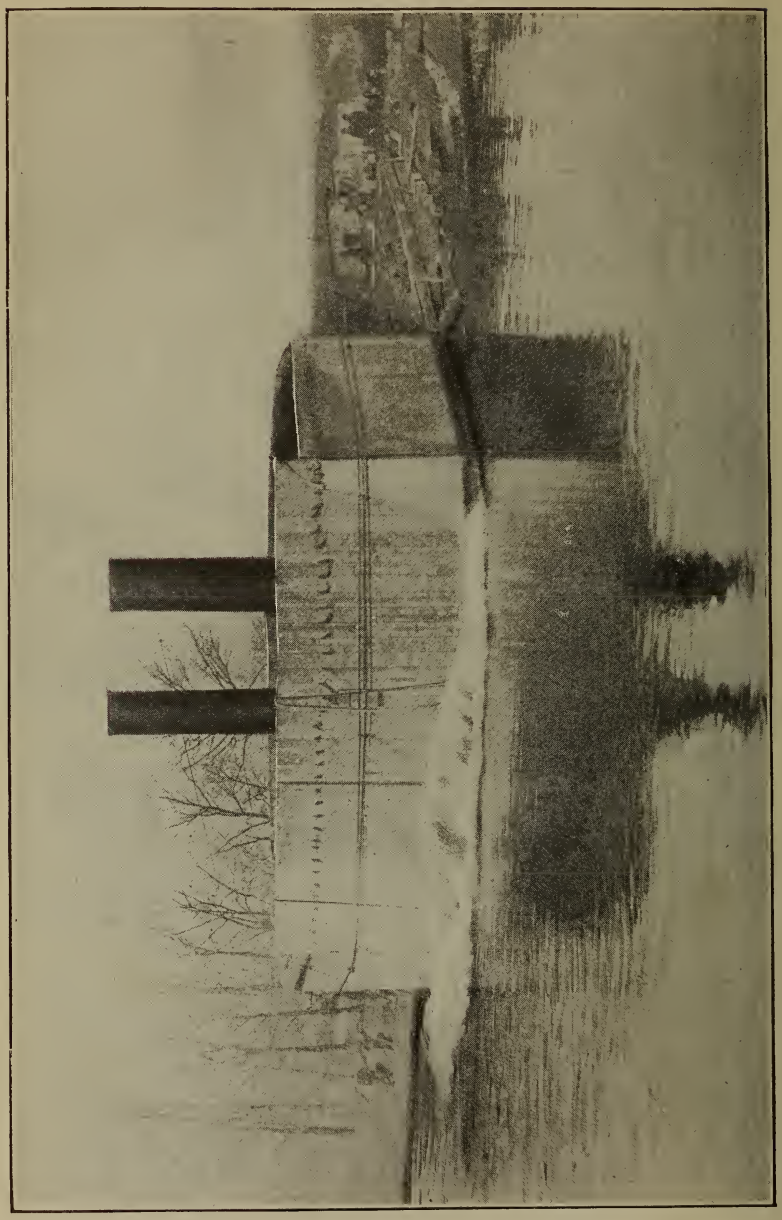
The third method consists of building on a temporary platform and lowering into position by means of screw. It is used where there is not enough water to float the caisson, and where it is not economical to dredge a channel. I might state here that concrete is the only rational material to put on the deck of a caisson. In sinking river caissons, as a rule, there is very little danger of injuring adjoining property, although there are cases where there is danger of undermining an old pier, and care has to be exercised to prevent the caisson being carried away. This indeed actually hap-



CAISSON BEING BUILT ON SHORE.—KINDNESS OF MR. LOUIS L. BROWN.

pened out West, and locomotives were hitched to it to try to hold it. In Nova Scotia, also, an iron caisson was carried to sea in a storm and never found. There is also danger of a caisson turning turtle, especially if not properly designed. A river caisson was once filled with concrete in the air chamber. The railroad officials, however, were afraid of concrete, and they allowed the contractor to put only a few feet of this material on the deck. Before the masonry was started an exceptionally high tide occurred which broke the bond of the concrete with the rock and lifted the whole mass, which had to be dynamited after being towed away. If the men in charge had taken the trouble to calculate the buoyancy, this accident would never have occurred, as 6 inches more concrete would have saved it. In another case the foreman used too big a charge of dynamite and blew the end out of a caisson which was just ready to sink. In one case a very expensively designed caisson was sunk for some water works. A water pipe about 8 feet in diameter was carried up from a tunnel below through the air chamber to the surface and the whole work completed. The air chamber, for economy, had been filled with sand instead of concrete, and when the water pressure against the roof was sufficient to raise the whole caisson, the big water pipe of course gave way.

It is a simple matter to calculate the air pressure, the weight of the materials, etc., but, as we have seen, the failure to do this has resulted in many serious accidents. There have also been many accidents to land caissons, but generally of a different nature. The first caissons to be built under a sky scraper were for the Manhattan Life Building, in 1894, and Mr. Francis H. Kimball, one of New York's best architects, deserves the credit for having the courage and foresight to insist on a rock foundation by means of caissons. Owners and architects were very slow to follow his example, which was considered a freak at the time, but now they are rapidly coming to see the necessity of having a foundation that will not be undermined by an adjacent building or future tunnel—a danger which can be better appreciated when it is known that all of lower New York rests on a bed of quicksand, which flows like water.



LAUNCHING CAISSON, FORDHAM HEIGHTS, HARLEM RIVER.—KINDNESS OF MR. L. L. BROWN.

Under the quicksand is found more or less hardpan, some good and some very poor. The bed rock itself, though sometimes decomposed quartz, is generally what we call New York gneiss, fully good enough for any load it will have to carry, which is limited to 12 or 15 tons per square foot, the load allowed on concrete by the New York building laws.

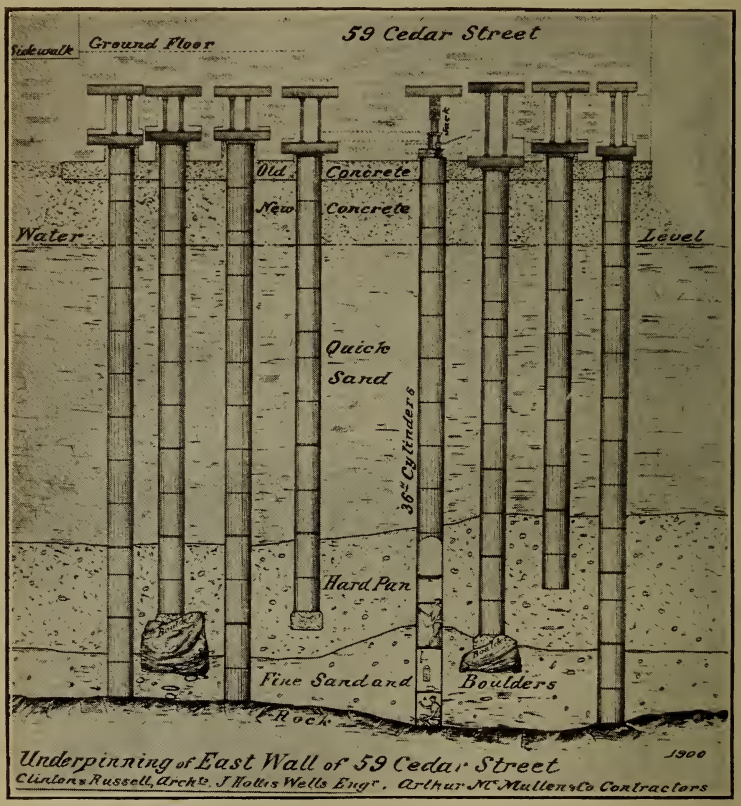
All sorts of liberties have been taken with New York caissons, with very expensive results. For instance, the caisson itself has been made so weak that the sides have collapsed. In a certain caisson which was 8 feet wide originally, a 29-in. bucket could not pass into the air chamber.

The caisson has broken away from the cofferdam above—necessitating tunneling down the rest of the way. An interesting case occurred here where the owners at first wanted their caisson stopped in good hardpan. After passing through 7 feet of hardpan, they decided that they wanted bed rock for their building. When an adjacent caisson was sunk, a tunnel was run to this caisson and the excavation carried down to bed rock 15 feet below. When this was filled with concrete, the other end was successfully undermined and filled up.

In one case a caisson was sunk with a temporary deck or roof. Four feet of concrete had been placed in the air chamber when the temporary weight and roof were removed to allow the column bases to be set. In the meantime, water pressure got busy and lifted the whole caisson bodily. It had to be blown to pieces.

In sinking caissons in the city, there is great danger, unless proper care is taken, of drawing the material from under adjoining structures, and many buildings have been badly cracked and thrown out of plumb 4 or 5 inches. In one case an open cofferdam, not very deep at that, caused an adjoining steel building which was nearly completed, to settle until it was about 16 inches out of plumb. In this case, the terra cotta floors were all taken out, and the building, at great expense, "jacked" back to its original position. In another

case, an elevated railroad structure had to be continually "jacked" up as the foundations settled, and the total settlement amounted to much over 12 inches. It is needless to say that most accidents of this sort are due to lack of experience and proper foresight. On one occasion a sub-foreman could not find any heavy timbers with which



THREE-FOOT CAISSONS UNDER AN OLD BUILDING.

to "shore" up a caisson which was standing 20 feet high, and in which excavation had just started. Instead of going to the superintendent he used a 3-in. plank for a "shore," with the result that the caisson toppled over and the concrete all had to be broken up.

An experienced man can generally tell how close to an adjoining building it is safe to sink a caisson without underpinning or "shoring." When the caissons are not close to the adjoining building, inclined "shores" are used, but if the caisson is very close to a heavy structure, it is necessary to take the weight off the old foundations by the old method of "needles," or by putting very small (say 3-ft. diam.) caissons directly under the building one at a time. This method has been described by me in one of my previous "papers" and in the Engineering News of March 28th, 1901. The method of forcing small pipes, say from 8 to 10 inches in diameter, under a building, has been tried a number of times, but is not reliable and has given trouble by allowing the building to settle after the pipes were all in place. The reason for this is that the pipes were too small to send a man down. Hence there was no way of telling if they were resting on a good bottom. When an adjoining caisson had loosened up the surrounding quicksand and destroyed the friction, the building would force the pipes farther down and would require to be "shored" up some other way. Of course, with a caisson from 27 to 36 inches, inside diameter, it is possible to get a good safe foundation, though at a considerable expense.

Filling the air chamber is a very serious matter, that does not receive as much attention as it deserves. There are two ways of doing this. One is to bench the concrete, starting at the sides and working towards the shaft, and ramming mortar or concrete directly under the roof of the caisson. This of course necessitates a very dry concrete, which requires a great deal more care than is necessary where wet concrete can be used. The other method is to fill the caisson nearly to the deck, take the air off and dump grout and very wet concrete down the shaft. This cannot be done in a very large caisson, and requires great care in a small one, as it is hard to make the concrete wet enough to spread properly down below. It is marvellous where the water goes to in such an operation. I have seen such concrete dumped in a shaft where there was no escape for the water, and where one would expect to find slush in the shaft. Instead, one would find fairly dry concrete. No concrete expert

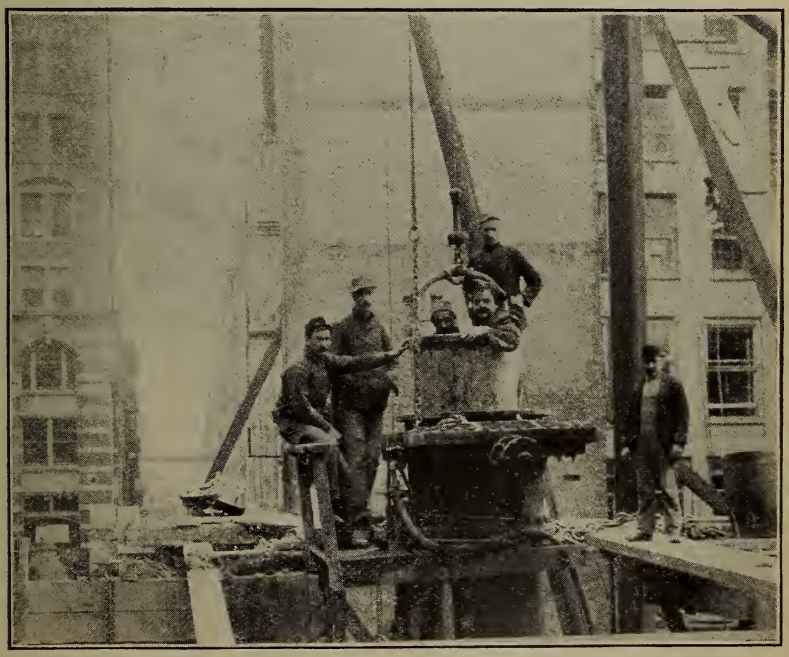
would believe, without seeing it tried, that so much water would be required.

We often hear some one talk of mysterious failures of concrete in the open, or say that he has examined a caisson which has been removed, and found that the concrete had not set up properly under air. After putting in a great many thousands of cubic yards of concrete, both in compresed air and out of it, I am absolutely satisfied that any failure of Portland cement concrete is due, not to the materials, but to the ignorance or carelessness of the men mixing and handling. This of course is under the assumption that a reliable cement is used, and that the materials are up to the specifications. I am satisfied that the so-called mysterious causes would be easily explained if the process were carefully watched. For instance, one frequently sees a contractor transporting wet concrete in a bottom dump bucket from which the water and cement are escaping, leaving the sand and stone in the bucket. As to concrete not setting up in compressed air, I know from many examinations that the concrete in compressed air sets up quicker, and as well as, if not better, than out of it. At least 12 hours should be allowed for setting before the air is taken off, especially where the concrete will have to withstand the pressure of a head of from 50 to 100 feet of water. It has been claimed that concrete can not be made water tight, and we have known of cases where the water has found its way up through a pier 90 feet high. This is probably true of the old fashioned dry concrete, but with care I have made a water tight layer of concrete under air pressure, about a foot above the cutting edge, which was sufficient, after the caisson had been filled, to prevent a head of 85 feet of water from percolating through. The trouble of concrete freezing in a caisson does not exist, provided that it is not frozen before it enters the lock.

Sand hogs, as the men who work in compressed air are called, are probably the poorest paid of all labor unions, considering the amount of work they turn out. The increased amount of oxygen makes them work hard and well as a rule, and gives them good appetites, for one seldom sees a lean sand hog. The work however

consumes their energy and there are not many old men among them. They used to get $2.50 for an eight-hour day, that is 7½ hours actual working time, and a half hour in the middle for lunch. Now the union in New York have had this raised to $3.50.

This is for pressure up to about 20 pounds per square inch. Above this the hours decrease and the pay increases as the high limit is approached, which is about 45 pounds per square inch. At



A MUTUAL LIFE CAISSON, '00-'01.—SAND HOGS GOING TO WORK.

the high pressure, men work only about 45 minutes, twice a day, taking three hours' rest between two successive shifts. Even then, with short hours, the results are often fatal. The doctors can of course say that it is dangerous for certain men to go into compressed air—for we know a man must have a good heart and lungs and be in good condition. On the other hand, many who are apparently sound cannot stand the pressure. The first effect generally felt is

the pressure on the ear drums especially if one has a cold. The drums are often ruptured, causing intense pain. The next is what we call the "bends." This is supposed to be caused by the compressed air forcing itself into the pores and not escaping when the victim leaves the lock, causing pain and annoyance. Many have more or less severe attacks of the "bends" without serious results, but the next step is paralysis, from which recovery may be possible, or the trouble may last for life or prove fatal on the spot. One man was paralyzed during the last year in only 20 pounds of air, an occurrence hitherto unheard of at such low pressure. A remedy that will cure a man of the "bends" once may have no effect on him another time, as I know to my sorrow.

The purity or foulness of the atmosphere has also much to do with a man being "knocked out." In the Harlem river, which, to the disgrace of New York, is a big sewer, the bottom of which is intensely foul, we have sunk caissons and had much trouble with the bends. The trouble continued until the caissons got down to the hard clean clay, and though the air pressure was then much greater, the men suffered much less.

In winter, when the thermometer is down to zero, the air chamber is comfortably warm, but in summer the compressed air makes the air chamber very hot unless the air pipes, as they frequently are, are passed through tanks of water or ice. It is peculiar that as a rule sand hogs are almost useless on outside work, and even some high-priced superintendents who are very valuable in the caisson, can not earn their salt in the open air.

THE VALUE OF DESCRIPTIVE GEOMETRY IN ENGINEERING PRACTICE.

Norman R. Gibson, B.A.Sc.

It is safe to say that very few undergraduates in Applied Science, who have the subject of Descriptive Geometry on their curriculum, regard it as anything else than a difficult course, placed there as a means of expanding an already well filled time table. This was the prevailing opinion a few years ago and probably it has not changed much since then.

The purpose of this article is to draw attention to the fact that Descriptive Geometry is not an altogether abstruse science, but, if looked at from a common-sense standpoint, is a simple method of solving many problems that occur in practical designing. Its use is essentially adapted to designing, and those who look forward to a rigorous training in the drafting room will do well to consider their Descriptive Geometry carefully, and thereby save themselves much trouble, and provide themselves with a means of overcoming many difficulties.

Speaking generally, any piece of work of such magnitude or complexity as to require a drawing to make possible, or to facilitate, the construction of the work, must be shown in plan and elevation; these, usually, being the horizontal and vertical projections of the structure. If all the lines of the structure lie in either of these two planes, the problem of drafting is one only of simple orthographic projection, but, if any line is inclined to either of these planes, the problem becomes one in Descriptive Geometry. If any line is curved and not wholly in one of the projecting planes, the problem may be somewhat more difficult; and if the structure is represented

by a number of curved lines in different planes, the problem may become very complex.

It is readily seen that very often all the lines representing a structure do not lie in the horizontal or in the vertical plane, and hence the variety of applications that may be made of Descriptive

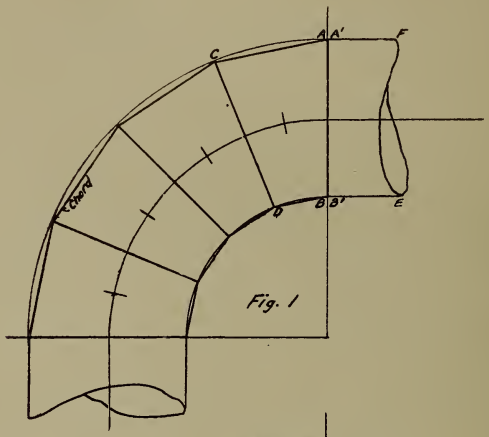


Fig. 1

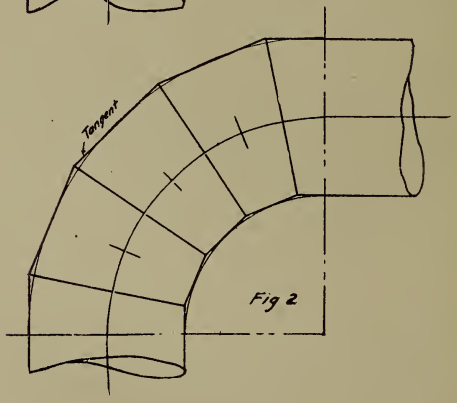


Fig 2

Geometry is at once suggested. The most common applications are found in the design of steel pipes, stacks and steel plate work in general, where drawing is made difficult by bends and intersections. In the design of reinforced concrete work, such as flared draft tubes for water-wheels, skewed arches, and complicated forms in general, the methods of Descriptive Geometry are not only useful but essential. One of the simplest problems, but one which often

occurs, is to find the true angle between two intersecting lines (e.g., the centre lines of a bent pipe) when given the horizontal and vertical projections of these lines. Another is to develop the plates of an elbow. A third is to determine the angle and size of bent plates for skew connections in structural steelwork.

It is impossible of course in the limits of a paper such as this, to describe in detail any complicated examples of the application of Descriptive Geometry to practical designing; but one case that has come to the writer's notice, and which frequently occurs, will serve to illustrate the point. In designing an elbow for a thick steel pipe of large dimensions, the segments of the bend were laid out as shown in fig. 1, which is apparently the more natural way to do it. A little application of Descriptive Geometry will show that the end A B of the course A B C D is an ellipse, and that the end A′ B′ of the course A′ B′ E F is a circle. The difficulty of fitting these two courses together can only be realized by practical experience. For the case in point, the error was not discovered until the plates were assembled in the field and considerable time and expense were involved in forcing the two courses together. A study of fig. 2 will show the correct method of laying out this elbow. The number of divisions is always twice the number of courses plus two and the segments of the elbow tangents to the curves instead of chords, thus maintaining the correct inside diameter of the pipe.

One word, in conclusion, with regard to the difficulties of Descriptive Geometry. It is safe to say that half the trouble in this subject is due to initial prejudice and the failure to apply some common sense. A little effort of the imagination and a little careful study will overcome most of the difficulties, though it must not be supposed that anything can be accomplished without a fair trial.

It is hoped that in thus drawing attention to the usefulness of Descriptive Geometry, its value will be made more apparent and the subject studied with a better idea of its ultimate worth.

NIAGARA POWER TRANSMISSION.

T. H. Hogg, '07,

During the past summer, the writer was employed by the Niagara, Lockport and Ontario Power Co., on the location of towers, and work incidental to the transmission lines, which are being constructed by that company between Niagara Falls, Ont., and Syracuse, N.Y.

As this line is the longest of its kind north of California, and one of the longest in the world, it will no doubt be of interest to members of the Engineering Society. It is not the intention, in this paper, to attempt to give the technical designs entering into the construction of the line, but simply to give a brief description of the line itself, the country it traverses, and some of the difficulties of its construction.

Power is generated by the Ontario Power Co. at Niagara Falls on the Canadian side, and conveyed across the Niagara River at a point near the Whirlpool, where the gorge is narrow. From there the line is carried on steel towers, placed on a private right-of-way, to Syracuse, N.Y., a distance of 160 miles, and to the other distributing points.

During the erection of the power plant at the falls, contracts for power, with delivery at a certain date, were made with the Syracuse Street Railway. Steel tower erection is of necessity a slow performance, so it became necessary to build a wooden pole line in order to fulfil these contracts. This pole line for most of the distance to Syracuse is placed on the West Shore Railroad right-of-way.

The design of the pole structures will be described later, as they are of a type different from the ordinary. The current carried on these poles is 60,000 volts, three phase. As there is not much of interest in this first line except its length, we will pass it over, and go on to a consideration of the more permanent line which is now being built.

With such a high voltage and its accompanying danger to the public, a private right of way for the location of the carrying structures is absolutely essential. The location of this right-of-way is governed by a number of factors, such as topography, railway and highway crossings, and cost of property. In traversing a section of country so thickly populated as New York State, and of such value agriculturally, this last consideration of cost of right-of-way is a large item. It is of course desirable to approach as near as possible to the larger towns and cities along the route, in order that tap lines to these may be cheaply erected. On the other hand, the more nearly the towns are approached the higher is the value of the land. These elements must be balanced one against the other.

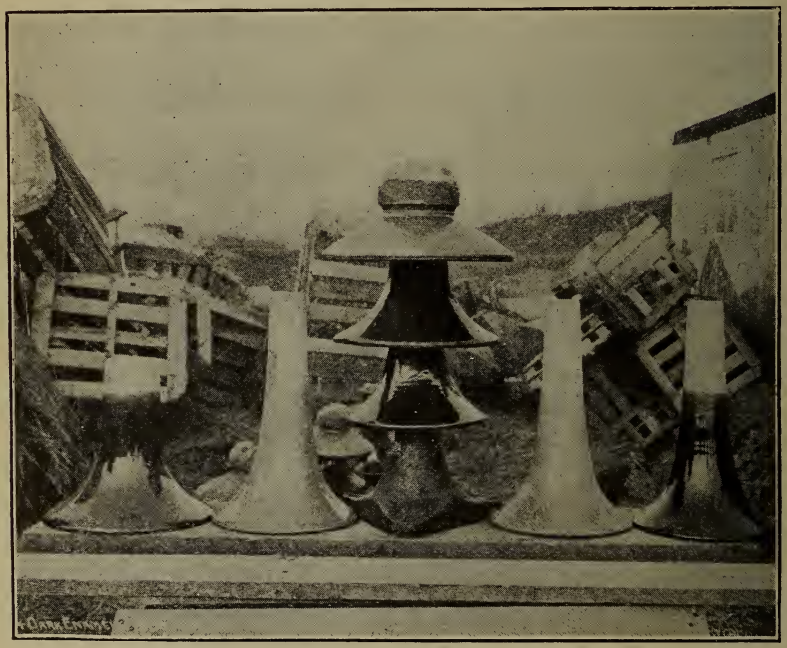
Railway and highway crossings are also a great factor in the location, as it is advisable to have these crossings at right angles, or as nearly so as possible, in order to have ample clearance of the circuits. The topography of the country enters to a less extent into the consideration of location, as, with towers of different heights and spans of different lengths, the engineer has at his disposal a very flexible arrangement with which a very fair grading of the line can be secured, even in rough country.

Angles are avoided as much as possible, because of increased cost, as extra towers are required at such places. Further, angles often occasion weak spots in the line where breaks may occur. Marsh land which extends any distance is also to be avoided, on account of the difficulty of securing good foundations for carrying structures, and also because of the trouble incidental to getting construction material on the ground.

The width of right-of-way varies according to the number of lines to be built. From the transformer station at Niagara Falls

to the sub-station at Lockport, a distance of about 18 miles, the width is 300 feet, to accommodate six lines. At Lockport there is a division, right-of-way for three lines being obtained to Buffalo and right-of-way for three lines to Rochester. The width of a branch line right-of-way varies from 10 feet to 50 feet, according to the number of lines, the former being the width for one pole line.

The carrying structures are of several different kinds, and as they are all somewhat novel in this class of work a detailed descrip-

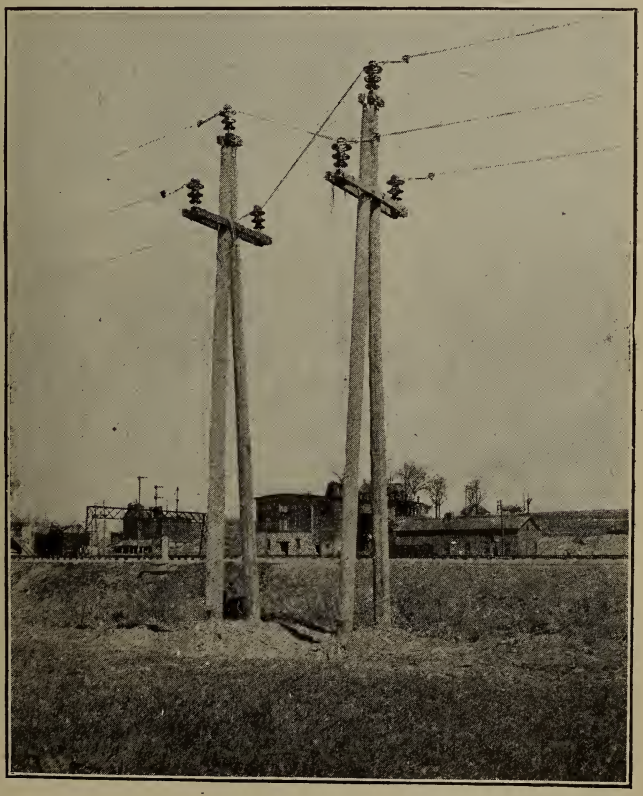


INSULATOR FOR 60,000 VOLTS.

tion of each will be given. The type first used on the Canadian side for low voltage circuits was a single wooden pole with wooden cross-arm, set into the centre of the pole and held firmly with wooden pins. The three-phase current was carried on this, one cable on the top of the pole and one at each end of the cross-arm. It was the intention at first to use this style of structure on the branch lines for heavy voltage work, but it was found that they

were far too light and unstable to carry the relatively heavy loads due to the weight of insulators and cables, and to wind pressure and ice.

Some idea of what this weight is, may be had from the fact that a single insulator and steel pin for 60,000 volts weighs 75



"A" FRAME, SHOWING TRANSPOSITION OF CABLES.

pounds. A number of short experimental lines of these poles were erected, radiating from the Falls sub-station, and these are now being used for the low voltage local transmissions.

The other carrying structures may be divided into two classes, those used on main lines, and those used on branch lines; but on

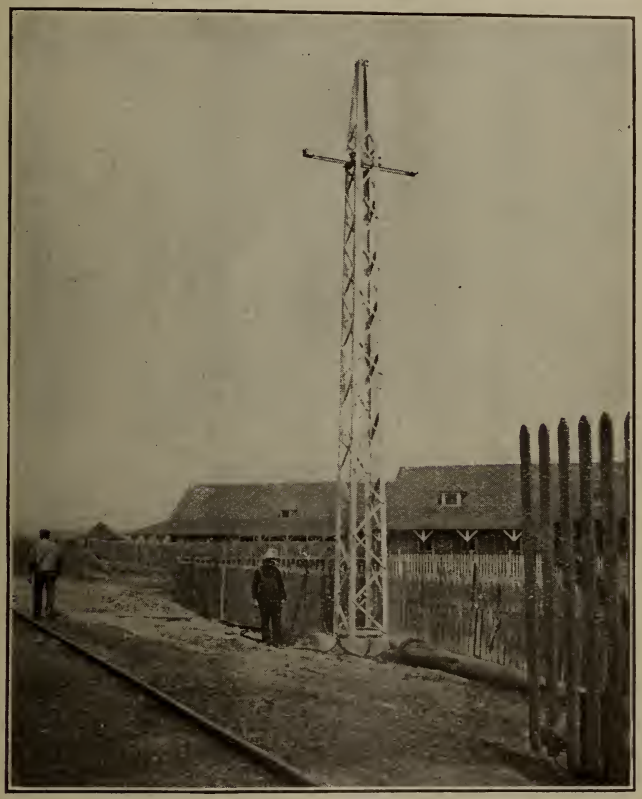
none of them are there more than the three wires of a circuit. In this will be noticed a difference from the Electrical Development Co.'s main line to Toronto. There each tower carries two circuits. The Canadian Niagara Power Co.'s line from Niagara Falls to Buffalo is similarly constructed. The reason for placing only one circuit on a tower is to obtain as complete an isolation of circuits as possible. A distance of 25 feet is in all cases maintained between circuits. Should any accident happen whereby a tower is injured or destroyed only one circuit will be affected.

The branch line structures are of two kinds,—those known as A-frames, composed of two wooden poles, and latticed steel columns with concrete foundations. Since doubtless but a few of those present have seen the A-frames, a description of them will not be out of order. As the name implies, they are made in the form of the letter A, and consist of two poles with a spread at the base of five feet, where they are tied together with two 2″ x 12″ planks. The cross-arm forms the bar of the figure A, and at each end of the cross-arm is placed one wire of the circuit, the third wire being carried at the apex of the poles. A distance of 7 feet is preserved between wires. These poles vary from 40 to 60 feet in height. The frames are placed at right angles to the line and form a very stiff arrangement.

The maximum span used is 220 feet. The necessities for varying this span will be dealt with later, as will also the reasons for strengthening the line by guys, etc. Heavy cast-iron pins $2\frac{1}{8}$″ in diameter are used to carry insulators, which are of the petticoat type, with three petticoats, the top one being 15″ in diameter, and the whole standing 20″ high. The insulator pins are carried on the poles in heavy cast-iron sockets firmly bolted to ends of cross-arms, and to the top of the poles. These insulators, which are used on all the company's high voltage work, come in three sections, and are cemented together and to the insulator pin with neat cement.

The latticed steel columns, which are used on the branch lines to a limited extent, come in standard heights of 31′, 50′ and 60′

respectively. They are made up of four rather heavy angles, and vary from $2\frac{1}{2}'$ to $3\frac{1}{2}'$ square at the base. They are latticed with lighter angles. The cross-arms are riveted to columns at six feet from top, and here the corner angles begin to converge, meeting at the apex to furnish a support for the peak insulator.



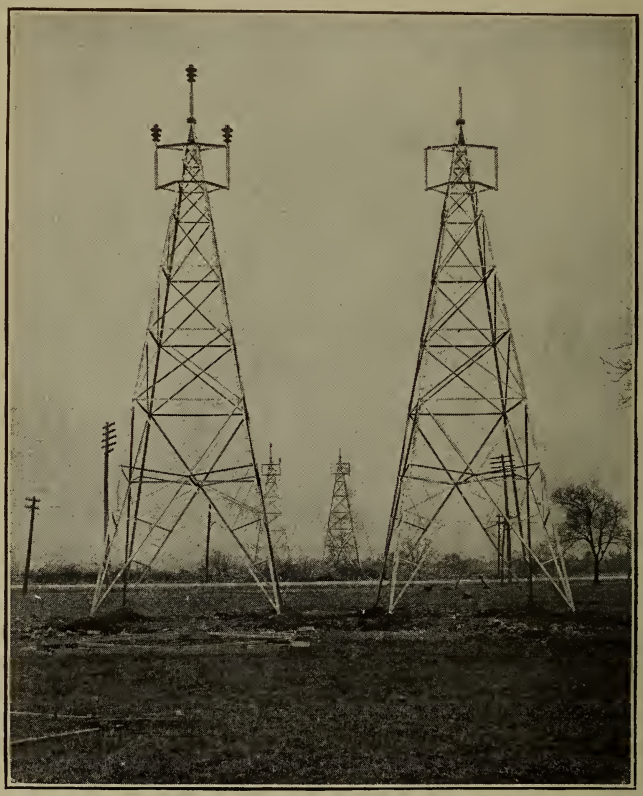
STEEL POLE.

These columns are imbedded in a concrete foundation, 5′ square, and extending 8′ in the ground, with a footing course 5′ x 8′.

The adjacent tangent spans allowed on these towers are 300′, 400′ and 325′ respectively, for the heights, 31′, 50′ and 60′. They are used only where it is necessary to have a stiffer structure than

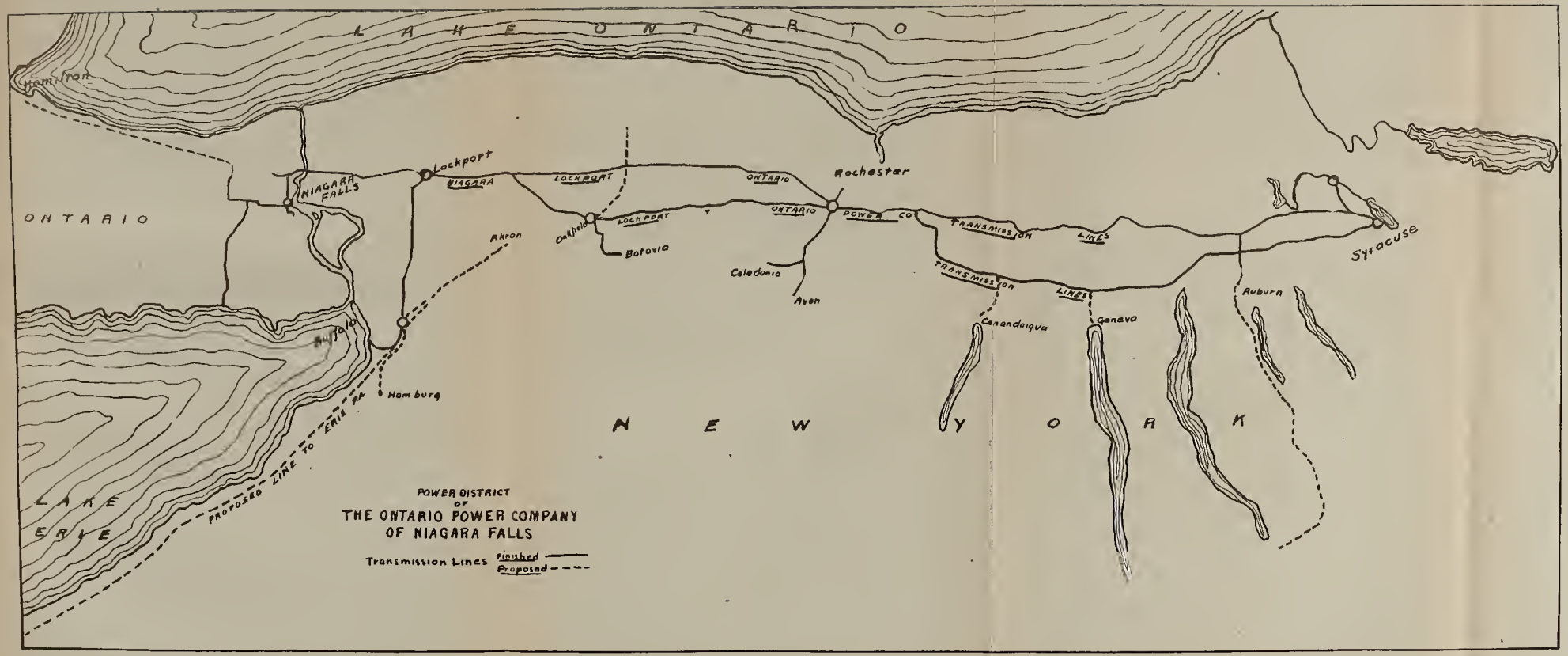
the A frame, with no room for guying, and where a longer span is necessary than can be obtained with A-frame structures.

The main line towers are of two forms. The form first used, but which has now been superseded, is called the Archibald-Brady tower, from the name of the contractors who submitted the design



AERMOTOR TOWERS.—BUFFALO LINE.

and supplied them. These are of steel, with triangular bases and hollow tubular legs, each leg having a heavy concrete anchorage. Unfortunately these towers have hardly had a fair test, for they were erected during the winter in freezing weather, and the tubular legs were filled with grout, with no provision for allowing moisture


LAKE ONTARIO
Hamilton
ONTARIO
NIAGARA FALLS
Lockport
NIAGARA
LOCKPORT
ONTARIO
Rochester
Akron
Oakfield
LOCKPORT
ONTARIO
POWER CO
TRANSMISSION
LINES
Batavia
Caledonia
Avon
Syracuse
TRANSMISSION
LINES
Auburn
Canandaigua
Geneva
Buffalo
Hamburg
NEW YORK
LAKE ERIE
PROPOSED LINE TO ERIE PA.
POWER DISTRICT
OF
THE ONTARIO POWER COMPANY
OF NIAGARA FALLS
Transmission Lines Finished
Proposed

to escape, consequently the grout froze, and expanding, split the tubes, necessitating a considerable outlay for repairs. However these towers are hardly considered heavy enough for the work, and they are no longer being used.

The style of tower universally used now, is what is known as the Aermotor and is made by the Chicago Aermotor Co. These have square bases, and are made up of angles and light rods, each part being galvanized, thus doing away with the necessity of painting. They come in standard heights of 42′, 49′, 57′ and 75′. The spread of base varies from 15′ to 18′. The foundations for these are of concrete,—mixture 1 : 3 : 5, wedge-shaped to a depth of 5 feet, with a footing course 4′ x 5′. The towers are connected to the foundations by anchor bolts 5′ long, with a heavy washer imbedded in the footing course, the footing being reinforced with expanded metal.

The procedure during construction of foundations and erection of towers is as follows: The centre of the tower is located on the ground, with reference points from 10 to 15′ at right angles to it. The holes for the foundations are then laid out by template, and the anchor bolts located in the same manner. The forms are then placed about the anchor bolts and filled with concrete. After a suitable time has elapsed in order to allow concrete to set, the towers are assembled and erected. The towers are shipped in pieces and are assembled where they are to be erected. All joints and connections are made by bolts, no field rivets being driven. The delicate part of the work comes in the erection. Several methods are used, depending on the nature of the ground and the judgment of the foreman in charge of the work. Where a double line of towers is to be erected, the first line is usually erected with a gin pole, the second line being erected from these, using the towers already placed as gin poles. Extreme care is necessary in raising the towers to a vertical position, as the material used in their construction is rather light.

In all cases where undue strain is likely to occur in a structure, guys are used. These are of 7-16″ steel cable, anchored in the

ground with concrete deadmen, and attached to towers at the base of the lower insulators. Where a structure is guyed it is always necessary to use cable clamps, in order to transmit the stress from the carrying cable to the insulator, and thence to the guy; otherwise the stress would be carried into the next span and in all probability the binders fastening the carrying cables to the insulators would be torn off. It is usual to use two or more insulators in place of one, on guyed towers.

SHOWING ATTACHMENT OF GUYS TO TOWERS.

The maximum length of span between carrying structures is 220 ft. for the A-frames, and 550 ft. for steel towers. The reasons for varying the length of spans will be briefly given in the case of the steel towers, and what may be said with reference to them applies equally well to the A-frames.

On a long piece of tangent, with no angles or curves, various things may occur to prevent the use of the regular span, such as

creeks, railway and highway crossings, swamps, etc. There will therefore be certain controlling points which can be passed only by a certain arrangement of towers. For example, in the case of a creek crossed diagonally, it would probably be necessary to place the towers at equal distances from the shore on firm ground, not exceeding the allowable span.

These controlling points being located, the intervening spaces may be divided into equal lengths of maximum span. This constitutes the preliminary lay-out and is of course subject to slight changes, as certain of the towers thus located may, on examination of the line, be found to fall on ground unsuitable for foundations, so that by shifting the location a few feet either way, good foundation may be secured.

On rough ground it is also necessary to arrange towers so as to secure a fair grading of the line, and yet to keep the spans as nearly equal as possible so that the loads on the towers may be nearly equalized. This consideration of grading the line is materially aided by the fact that there are varying heights of towers.

A standard arrangement of towers is used at railway crossings. Guyed towers are erected as close to the railroad right-of-way as possible. The guys lead away from the railway, thus forming a tight span with small amount of cable sag over the tracks. The next adjacent spans on each side of this tight span are of a maximum length of 150 ft., and guys are so arranged as to make these spans slack. The succeeding spans are of standard length. This arrangement necessitates that the towers adjacent to railroad shall only carry the single span over the tracks, and that stresses which may occur in the tangent will be taken up in the slack span, without affecting the towers carrying the tight span. At important highway crossings it is usual to shorten the span to about two-thirds of the maximum, so that with the ordinary height of towers the carrying circuits may have ample clearance above telephone and despatch lines.

Where a change of direction of tangent occurs, it is made by turning the angle abruptly or by a curve. Two methods are used for

turning the angle abruptly,—by turning on two towers and by turning on three. In the first method, the towers are placed at equal distances from the intersection of the tangents. This distance is never more than 30 ft., thus making a span of slightly less than 60 ft. between towers and giving ample room for the two sets of tower foundations. The adjacent towers on each tangent are placed at distances of 150 ft. The angle towers are guyed towards the intersection of the tangents, while the next adjacent towers are guyed both ways. This arrangement relieves the angle towers of any stress which may occur in the tangents and leaves a short slack angle span.

The second method is a modification of this,—by turning on three towers. It is used for sharper angles than the preceding arrangement. Towers are placed 90 ft. distant from the intersection point on each tangent, and these are guyed towards the intersection. The third tower is placed midway between these towers in such a way that the deflection at it is a third of the whole angle. The next adjacent spans on the tangents are of standard length, and the towers are again guyed towards the intersection. This arrangement is more clumsy in appearance and can hardly be considered as satisfactory as the first method.

When it is necessary to turn an angle with a curve (and the reasons for this will be given later), a schedule of allowable spans with maximum deflection angles is used, and these must not be exceeded in the lay out. The allowable span for a certain curve being found from the table, the deflection angles for chords of this length are calculated and the curve laid out on the ground, the reference points for the tower foundations being placed on the radial lines of the curve.

The last tower on each tangent is guyed towards the intersection.

Protective structures are used at telephone crossings, and often also at railroad crossings where required by the railway companies. These are usually made up of a double line of poles strongly guyed

and covered with a network of cables, which form a cradle to catch any carrying circuit which may become broken or detached at the crossing.

This network is well grounded. Different protective devices are also used on the towers themselves. These devices prevent a broken live cable from coming in contact with the tower and afford a ground for the current. The dangers ever present with such high voltage

PROTECTION STRUCTURE AT RAILWAY CROSSING.

transmission are just beginning to be appreciated now, and the requirements for more and better protection at all highways, railroads and public crossings, are becoming far more rigid than they were a year or so ago.

A clearance of circuits above ground of 25 ft. is maintained. This is increased to 30 feet at important highway crossings, and at railroad crossings; at telephone crossings 12 feet is preserved be-

tween circuits and telephone lines. When running parallel to dispatch wires for any considerable distance, to offset the induction which is set up in these lines, it is usual to transpose the carrying circuits every five miles, rotating them through 120°. This rotation sets up contrary induced currents which counterbalance each other.

A table of allowable sags for different spans is used in stringing the cable. This table gives for different temperatures the ver-

SPLICE IN CABLE BEING MADE.

tical sags with which the cable must be strung so that with wind and ice at 40° F., the elastic limit shall not be exceeded. The cable used on all main lines high voltage work is aluminum, 642,800 C.M., 0.505 sq. in. area, 0.925″ extreme diameter, and containing 19 wires. The elastic limit is 12,500 lbs. per sq. in., the modulus of elasticity being 9,000,000, and the co-efficient of expansion 0.0000128 per degree F. The computations are made assuming as lowest temperature, 40° F., with $\frac{1}{2}$″ of ice all around the cable, and a wind

pressure on the rounded surface of the ice covered cable at 15 lbs. per sq. ft. of section. The weight of aluminum is 0.588 lbs., and that of ice, 0.889 lbs. per ft. of cable.

Splices in the cable are made by means of a flexible aluminum sheath about 2.5 ft. long, which just holds the two ends of the cable at once. After placing the ends of the cable in this sheath, they are given five complete turns and this forms the joint. No heating is done during the operation.

Reinforced concrete poles have been much used of late for transmission work at Niagara Falls, by the other companies operating there, and the question might well be asked why this company have not seen fit to use them. The poles so far used have given very good results, being strong and compact, and permitting of easy erecting and cable stringing. They have, however, one serious disadvantage, which prohibited their use on the work for this company, and that disadvantage is the danger of breakage in erection and the consequent delay in constructing others. These poles are built on the ground where they are to be used, and after being made should be allowed to set at least two weeks before erection. Because of this each broken pole would occasion a serious delay.

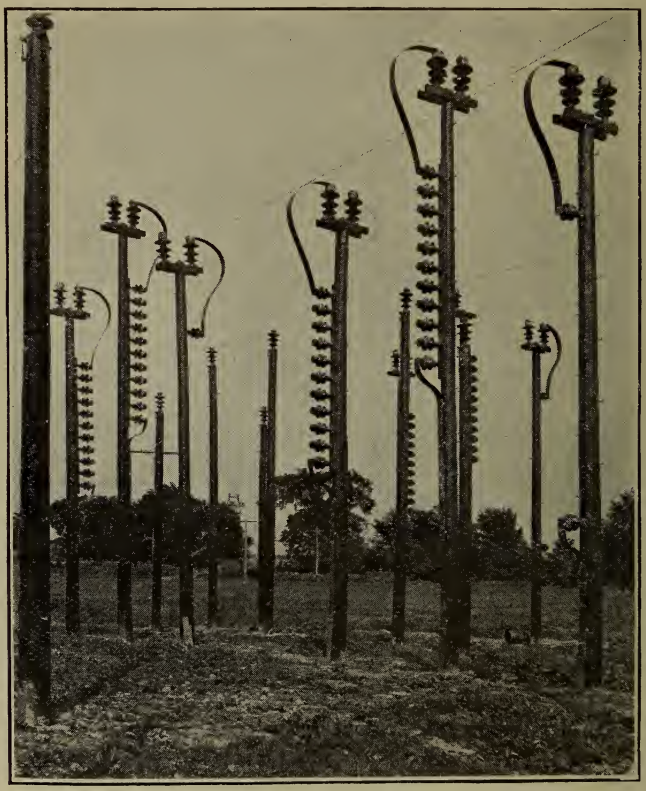
Where the right-of-way passes through wooded country, it is necessary to buy the timber rights on each side of the line to a distance of about 150 ft., in order that trees may not be blown over on the cables or carrying structures.

Sub-stations, equipped with step-down transformers, are located at all distributing points and terminals. These stations are all protected with lightning arresters and are of conventional design, so that there is no need of describing them.

It is of course necessary to patrol the line daily when it is in operation, to remedy any small trouble before it becomes serious and to make repairs (such as replacing insulators) where necessary. A patrol road is therefore built on the right-of-way between the lines of towers. This is graded and ditched and kept in good

shape for driving over. In some places the building of this road occasioned much trouble on account of the unstable nature of the ground. It was found necessary to corduroy it first and then cover with a couple of feet of earth.

A private telephone line connects the patrol stations which are placed about every twenty miles along the line. These patrol sta-



LIGHTNING ARRESTERS.

tions are comfortable little cottages of two stories, the lower floor being a store room for supplies for the line, while the upper floor contains the telephones and the living rooms for the patrolmen. There are telephone connections with the sub-stations by the private line and also by the Bell Telephone Co.'s System; so that if a break

occurs on the private line, the other is available. Three patrolmen are stationed at each patrol house, one always being there, while the other two are on the line.

Disconnecting switches are placed near these patrol stations, so that any section of the line may be cut out while repairs are being made.

The company has just finished the erection of the duplicate line to Syracuse, and a double line to Buffalo. It is the intention in the spring to proceed with a line to Dunkirk and Erie, Pa., with many short branch lines proposed and under way.

For the opportunity of becoming familiar with the work and for the many valuable suggestions received, the writer desires to express his thanks to the Resident Engineer, C. T. Rhodes, and to the Superintendent, W. S. Skinner.

A STEAM TURBINE POWER HOUSE.

C. L. Vickery, '06.

A few years ago the Brooklyn Rapid Transit, in order to meet their increase in traffic, began building the 3rd Avenue Power Station. This increase in traffic was due to a rapid growth of the population of Brooklyn. The suburban movement around New York has increased rapidly of late years, as the facilities for travel to and from New York have been improved. The opening of the new Williamsburg Bridge a little over a year ago greatly augmented this movement. At the same time, it gave the Brooklyn Rapid Transit a second entrance into New York. Another factor to be considered by this street railroad was the probable increase in the Coney Island traffic during the summer months.

Hence, even before their 3rd Avenue Power Station had been completed, the Brooklyn Rapid Transit saw that its output would be insufficient to supply the increased demand. They then began a little over three years ago to consider the project of a power station of greater capacity than any that had been before attempted. This station is now known as the new Williamsburg Power Station. When fully completed, it is expected to be able to supply the increased demand for some time to come.

The company owned a piece of land beside their old Eastern Power House, at the corner of Kent Avenue and Division Street, Brooklyn. This land had a frontage of 200 feet on Kent Avenue and a depth of 340 feet. The rear bordered on the East River. This property was considered admirably suited for power plant purposes. Hence the problem before their engineers was to develop the greatest amount of power in this limited space. This required a careful

examination of the various types of prime movers on the market as to their relative adaptability to come within the requirements.

After considering carefully these various types, in regard to economy in steam consumption and general running expenses, their engineers concluded that the steam turbine would be the most suit-

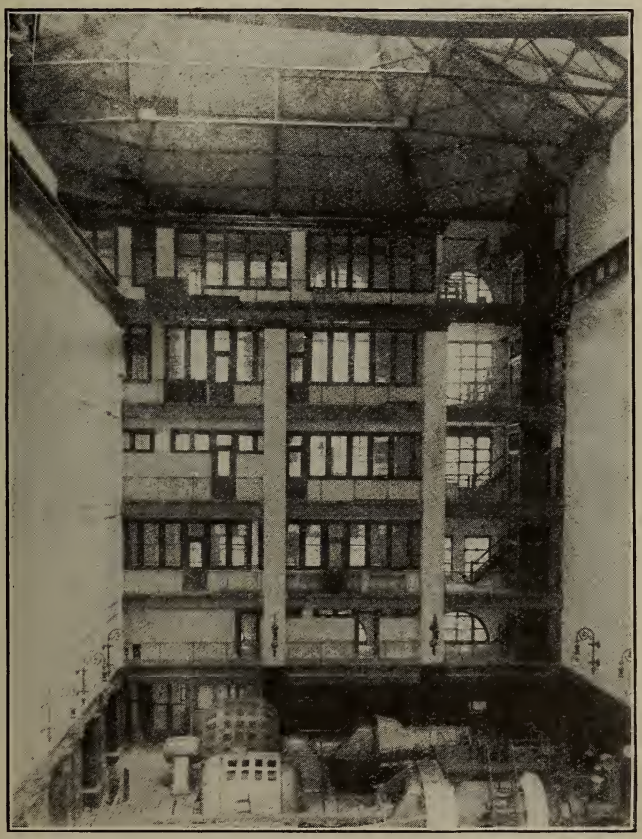


FIG. 1.—OFFICES, ETC.

able. When this decision was arrived at, no turbine of large size had been built. Hence this decision of their engineers was all the more remarkable, and showed great confidence in the future of steam turbines, and in the ability of their makers to fulfil any desired

requirements. The steam turbine had also the decided advantage of developing more power per square foot of floor space than any other type of engine. The first plans prepared called for 10 units, each 5,500 K.W. rated capacity, and capable of a 50 per cent. overload. But after ordering one unit of this size, it was decided to install in the remainder of the power house eight turbines of 7,500 K.W. each, rated capacity. Those with a 50 per cent. overload would make the total output of the station 100,000 K.W.

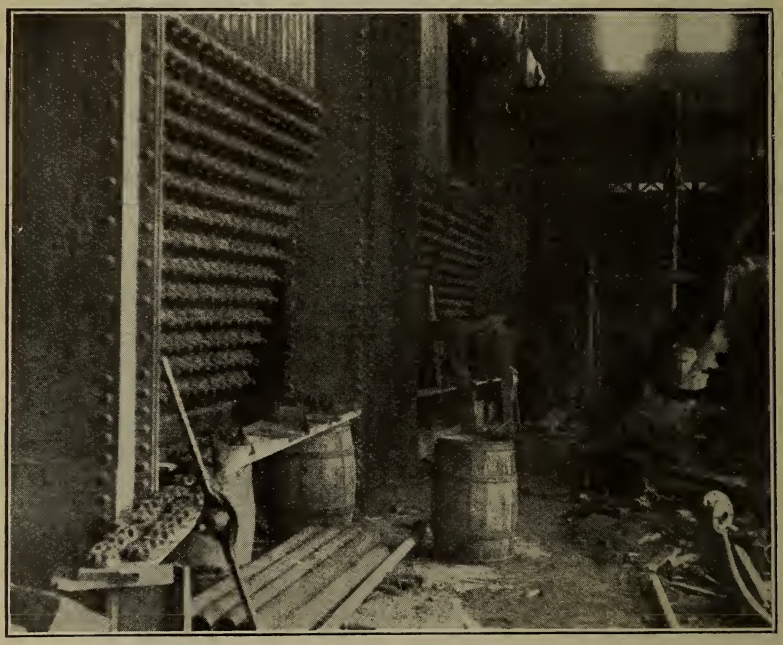


FIG. 3.—REAR VIEW OF BOILERS IN COURSE OF ERECTION.

The station so far completed consists of two boiler rooms, one above the other, each being 140 feet x 120 feet x 38 feet high. Below these is a basement 18 feet high in which are placed the boiler feed pumps, storage tank, heaters, ashpits, etc. Above the upper boiler room are large coal pockets. The turbine room is 140 feet x 60 feet x 60 feet high, each turbine occuping a floor space about 15 feet x 40 feet. Below is a basement 18 feet high, where the condensing

outfits are located. This room is equipped with a 50-ton crane, built by the Shaw Electric Crane Co., Muskegon, Mich. The heaviest casting to be handled after erection is the rotor, which weighs 46 tons. A commendable feature of the building is that plenty of room has been left for offices, testing rooms, wash rooms, etc. These are clearly shown in Fig. 1. At the north end of the building, which is to the left in Fig. 1, is the exciter room, 18 feet x 140 feet. Above it are galleries for the A. C. switch-board, the oil-switches, storage batteries, etc.

To produce sufficient steam for this amount of power, viz., 100,000 K.W., it was found necessary to have two decks of boilers one above the other, with 36 boilers on each floor. These boilers are of the Babcock and Wilcox Water Tube type, rated at 650 H.P. each, with a heating surface of 6,037 square feet, made up of 21 sections of 4-inch tubes, with 14 tubes in each section, and 3 drums, each 42 inches in diameter, 22 feet 2 1-4 inches long. The tubes themselves are 18 feet long. The grate area provided is 120 square feet, with a flue opening at the back of the boiler of 31 1-2 square feet. These boilers are built to carry a pressure of 225 lbs. with 100° F. superheat. The steam is superheated by being passed through U-shaped coils, located beneath the drums and above the upper row of tubes. The superheating area for each boiler is 308 square feet. It will be noticed that these boilers are suspended from the girders above, giving free expansion. Fig. 3 gives a back view.

At present there are only 36 boilers erected. These are arranged in 6 rows of 3 batteries each, 3 rows being on each floor. Fig. 4 shows one of these rows. Each battery consists of two 650 H.P. boilers. The superheated steam from each row is collected in a steam main running above the boilers at the back end. The steam main increases from 8 in. in diameter at the first boiler to 14 in. in diameter at the sixth boiler, where it then connects into a 14-in. vertical header. These vertical headers are cross connected to one another by the tie-pipes or equalizing pipes. The down-takes to the turbines are connected to these pipes at convenient points.

This makes a very simple and flexible arrangement and does away with the necessity of a relay pipe line. Each row of boilers may be considered as a unit which, by proper handling of the valves, may be used to supply steam to any particular turbine or to the general system. Also one or more boilers can be cut out in each row, for cleaning, without disturbing the general steam supply, since each

FIG. 4.—A ROW OF BOILERS.

boiler-header is fitted with a non-return valve, where it enters the steam main, besides the regular valves.

A somewhat similar method is followed in collecting the saturated steam for the auxiliaries. The main header is 6 in. in dia-

meter with a 2 1-4 in. pipe leading into it from each boiler. In all the steam lines there are no gaskets, the ground Vanstone joint being used entirely. All piping is extra heavy. At all points where condensation may collect, separators and traps are installed, the water from these being returned to the open heater.

Though a good system of steam distribution is essential to a modern power station, it is even more important to have a never failing supply of feed water for every boiler. Special attention has been paid to this fact as will be shown. The feed pumps, which are 3 in number, and of the Blake compound plunger type, may draw their water either from the open heater, or from the storage tank, or direct from the city mains. The water on leaving the pumps may pass either through the closed heater or by two other separate routes to the main feed lines, 8 in. in diameter, which run parallel with the boilers. These main feed lines are all connected at both ends, forming closed loops. This makes it possible to feed into either end of the main, and also to cut out sections of either line for repairs. Again at each battery a 3 1-2 in. pipe leads from the feed line up over the two boilers and down into the feed line again. This line has a 2-in. branch running to each drum and a valve between the two boilers. Hence it is possible to feed a boiler from either side. This arrangement of piping makes it very easy to get water to any desired boiler.

The grate surface, with an area of 120 square feet, consists of an 18-in. dead plate in front, and two rows of dumping grates each 3 ft. 9 in. deep. On account of No. 3 Buckwheat anthracite coal being used here, in accordance with the city by-law, which prohibits the use of soft coal, it was necessary to resort to hand firing. This is not as objectionable as might appear, since labor is comparatively cheap.

This coal is all conveyed to the station by water. A large coal hoist has been erected capable of handling 240 tons an hour. This hoist is built entirely of steel with galvanized siding. Fig. 5 shows the framework. The coal is carried to the top of the hoist by an endless chain of buckets, and dumped into cable cars, which carry

it over and deposit it in very large coal pockets above the upper deck of boilers. These pockets will hold a whole month's supply. From the pockets, chutes run down to each boiler.

The same hoist is used in the disposal of the ash. Small cars convey the ashes from the ash pits below the boilers out to a hopper

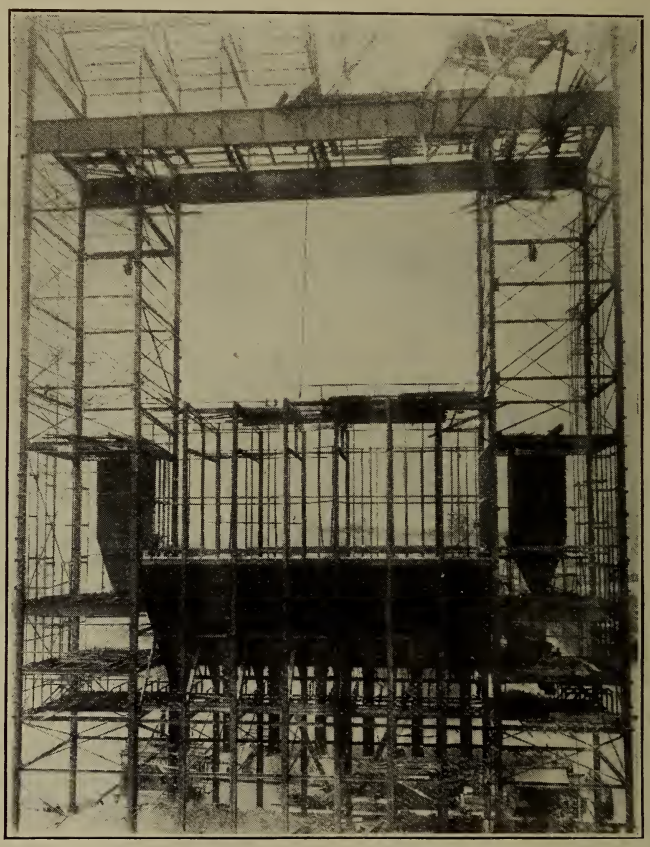


FIG. 5.—COAL HOIST, CAPACITY, 240 TONS.

at the foot of the hoist. From this hopper the ashes are elevated to pockets 20 feet above the tracks. They can then be loaded either on the company's flat cars or on river barges. A small Blake pump 7 1-2 x 7 1-2 x 6 in the basement is used for slushing down the ash pits.

The draft system was installed by B. F. Sturtevant, Boston. Beneath each row of boilers and between the ash pockets and the front of the boilers, is an air-flue with sectional area 24 square feet. At each end of this flue is a fan driven by a small compound engine 6 1-2 in. and 11 in. by 6-in. stroke. At peak load these engines run at 330 R.P.M., producing a draft behind the grate bars of 5-8. oz. or 1 inch of water.

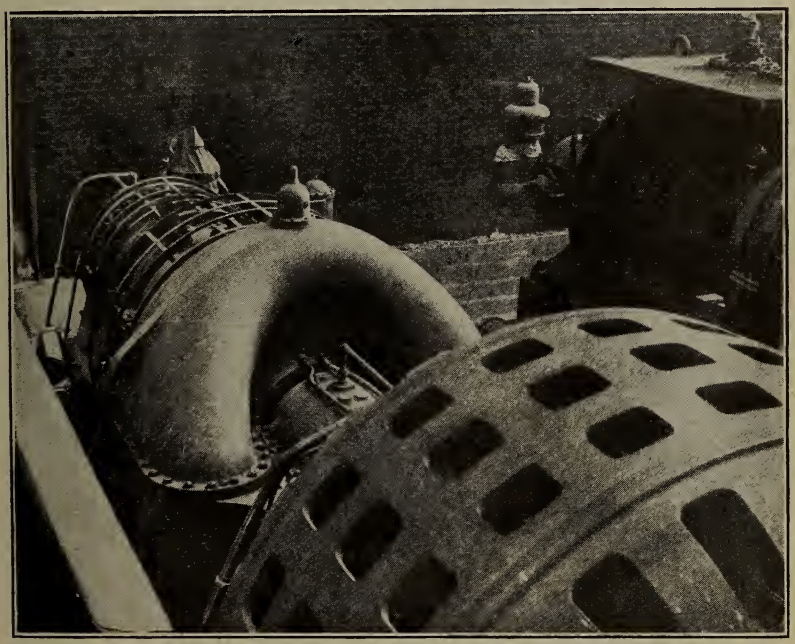


FIG. 7.—TOP VIEW OF ALLIS-CHALMERS TURBINE BEFORE LAGGING.

As the rows of boilers are placed back to back a common flue is built for every two rows with a cross-sectional area of 68 square feet. One flue on the first floor and the corresponding flue on the second floor, discharge their waste gases into a common chimney. This chimney, which is 20 feet in diameter outside, is made of steel lined with fire-brick for a distance of 50 feet, and with ordinary hard brick from there to the top. The chimney stands 210 feet above

the grates of the second deck of boilers. When completed the station will have three such chimneys. At present only two have been erected.

Turning our attention now to the turbine room, there has not been as rapid progress in erection as in the boiler house. The first machine to furnish power was an Allis-Chalmers turbine of the Parsons type, rated at 5,500 K.W. A top view of this machine is shown in Fig. 7. This machine has given excellent service since the date it was first under load, March 27, 1906, being out of service only five days since that date. This turbine is of far more than passing interest, as it was the first turbine that the Allis-Chalmers Co. had built. It had never run under load until put into actual commercial service in this station on the above date, when, on an hour's notice, it carried 4,000 K.W. for the whole afternoon. Many interesting articles have been written on the operation of this turbine, which may be found in the engineering journals of May and June of last year. Its excellent performance has thus clearly demonstrated that it can compete with any machine on the market. During rush hours it has carried loads of 9,000 K.W. (a 64% overload) for hours at a time, with momentary swings to 10,000 K.W. While a complete description of this machine would be very interesting and instructive, this paper deals with the power plant in general, and we cannot therefore go into the details. Figure 9 shows the steam end during erection. This shows the regulating device very clearly.

The turbine is direct-connected to a 3-phase Allis-Chalmers Alternator, built at their Bullock works. Figure 10 shows an end view of the Alternator and outboard bearing during erection. This Alternator has a revolving field making 750 R.P.M., and generating current at 6,600 volts. A remarkable feature of this Alternator is its low temperature rise, it showing only 25° C rise after a 24-hour run with a load of 6,000 K.W.

The next machine to get in operation was a Westinghouse-Parsons Turbine. This machine, partly shown in fig. 7, is rated at 7,500

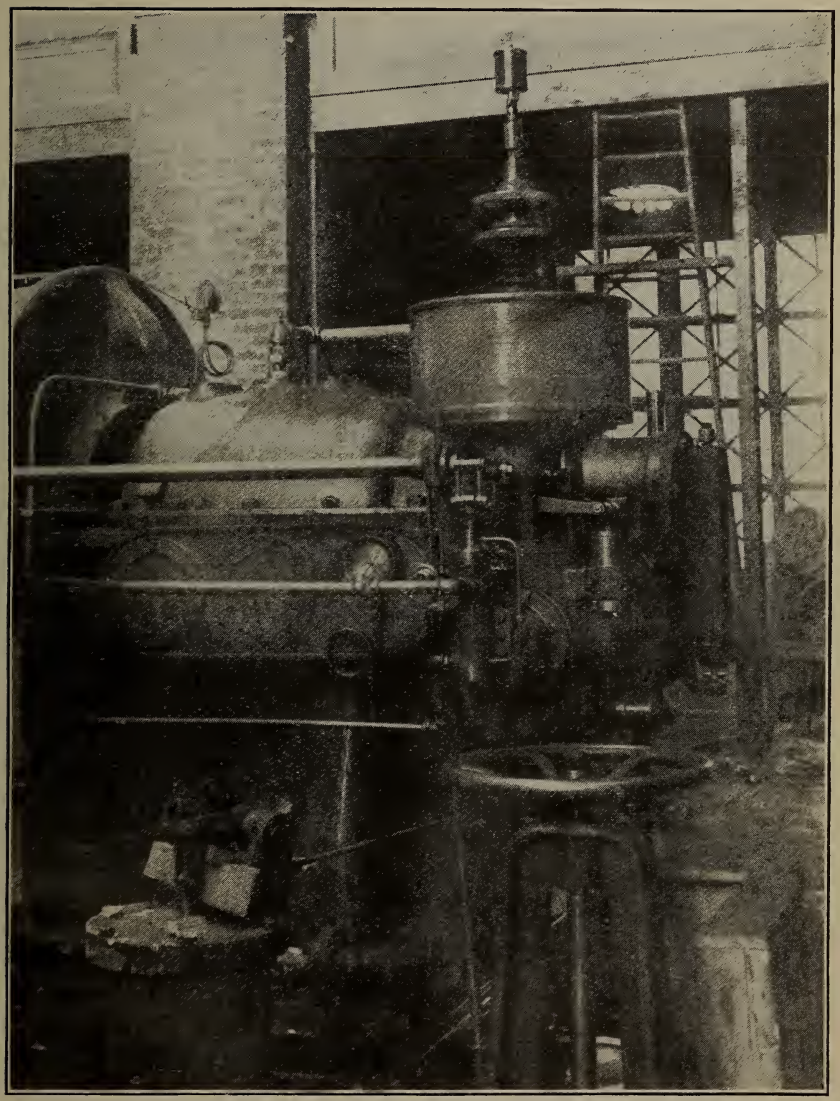


FIG. 9.—STEAM END OF ALLIS-CHALMERS TURBINE, SHOWING REGULATOR, THROTTLE VALVE, AUTOMATIC VALVE AND HIGH PRESSURE BEARING.

K.W., and carries during rush hours 11,000 K.W., an overload of nearly 50%. It is direct-connected to a 3-phase Westinghouse Alternator, with revolving field, giving current at 6,600 volts. Figure 11 shows a Westinghouse stationary armature, without the rotor in position.

At present each turbine has its own oil system, the oil being forced into the bearings by a pump driven direct from the spindle

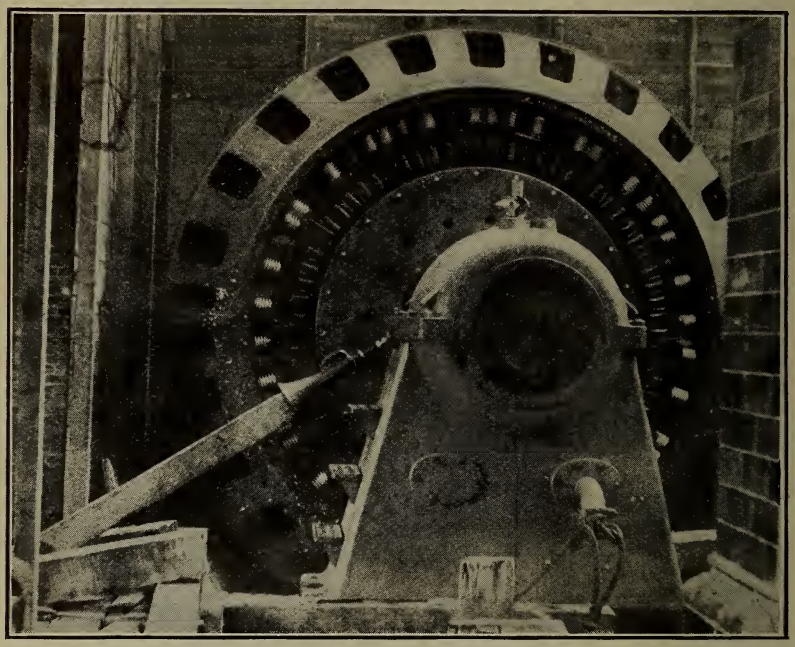


FIG. 10.—END VIEW, ALLIS-CHALMERS ALTERNATOR AND OUTBOARD BEARING DURING ERECTION.

shaft. A gravity oil system has been installed, but is not in working order yet.

These are the only two machines in operation at present, but work is being rushed on the other units, and another Westinghouse machine is expected soon to be in operation for the winter traffic. Figure 12 shows the two machines now in operation, and the bed-

plate for the third. Fig. 14 shows a Westinghouse rotor, also the lower half of the cylinder.

As the economy of a turbine increases rapidly for every inch of vacuum over 26 inches of mercury, the condensing outfits installed deserve mention. Both turbines have the same type of condensing outfit. It is only necessary to describe one of these.

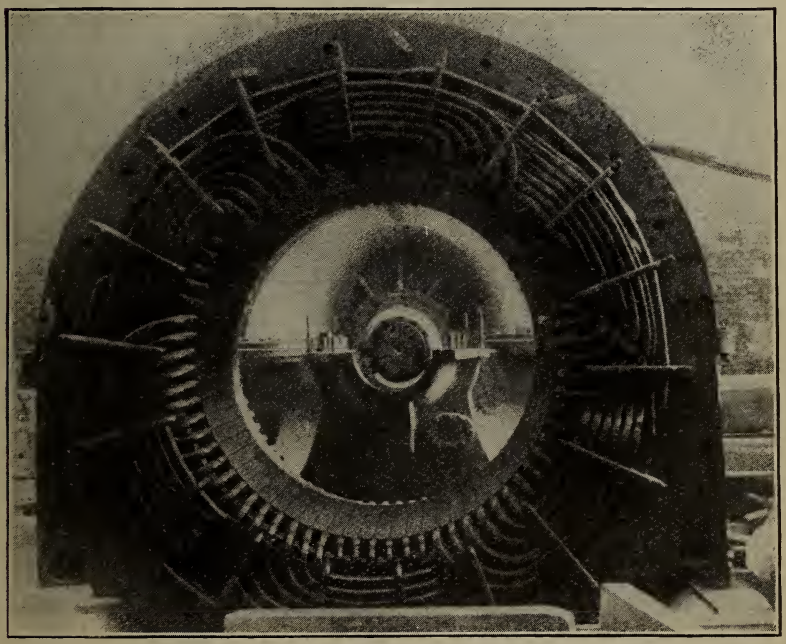


FIG. 11.—WESTINGHOUSE STATOR WOUND AND COMPLETED, READY TO RECEIVE THE ROTOR.

Since the steam in a turbine never comes in contact with any oil, the condensed steam may be returned as feed water direct to the boilers. Again as there was an abundance of cooling water close at hand, surface condensers were considered more suitable. Hence, the exhaust end of each turbine is connected by a suitable expansion joint to a Worthington surface condenser of the counter-current type, with 3 passes of water. The cooling water is forced

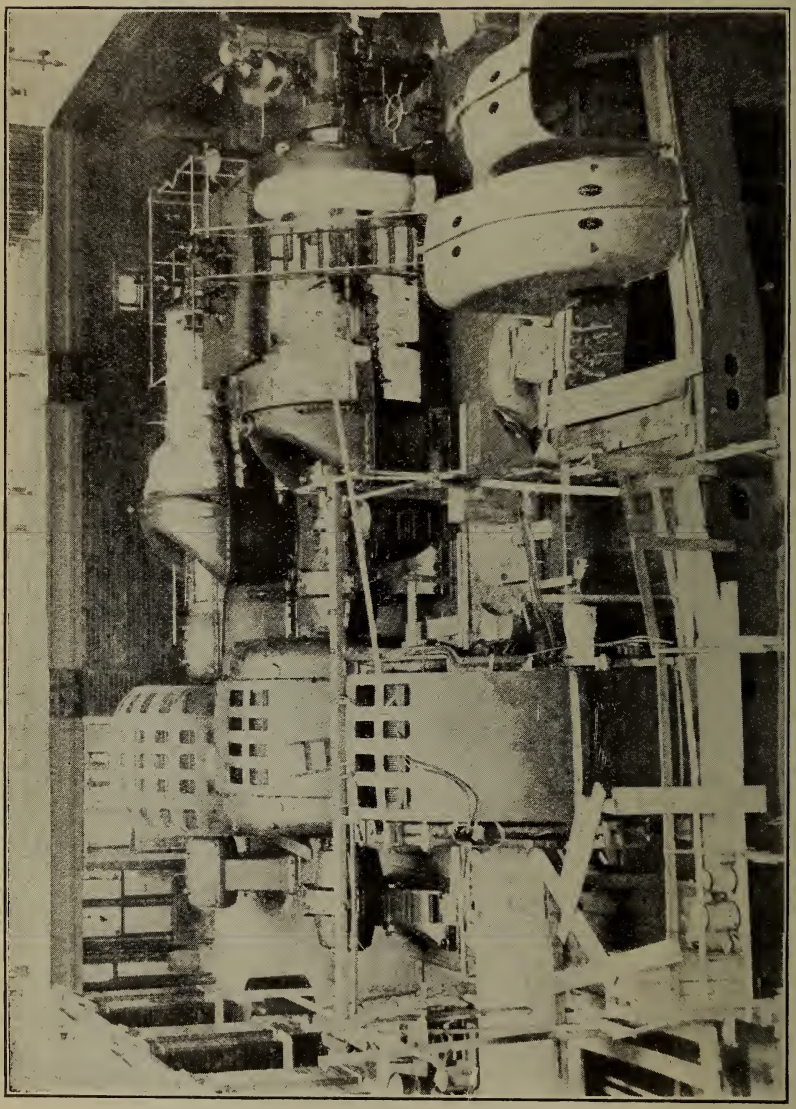


FIG. 12.—ALLIS-CHALMERS TURBINE AND WESTINGHOUSE TURBINE.

through the condenser by a 30-in. centrifugal pump, driven by a Reeves Compound Engine. The cooling surface of the condenser for the Allis-Chalmers turbine is 22,000 square feet, and for the Westinghouse turbine 25,000 square feet. These cooling surfaces consist of brass tubes 1 in. in diameter and 16 feet long. The condensed water is drawn off by a two-stage vertical centrifugal pump driven by a motor. This pump may discharge into the open heater, the storage tank or the sewer. A Worthington dry air pump 12 in.

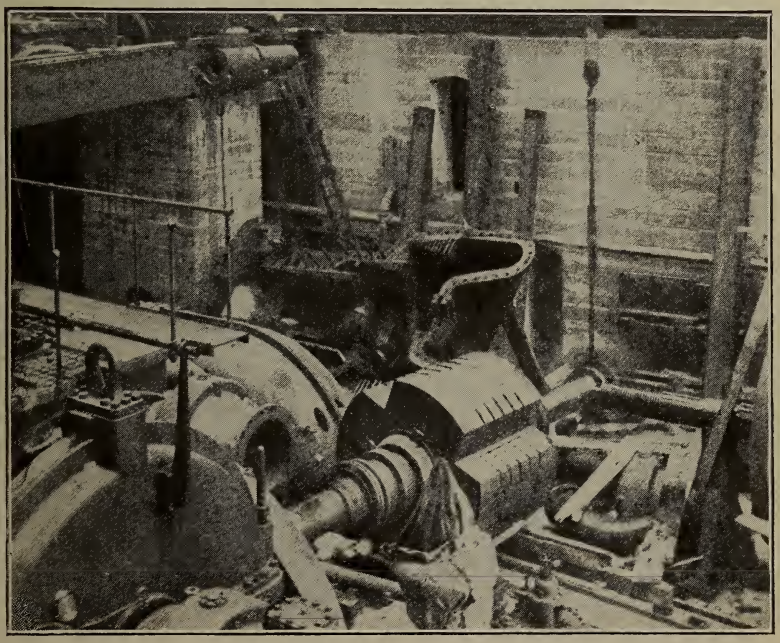


FIG. 14.—WESTINGHOUSE ROTOR.

and 30 in. by 24 in. stroke, running at 60 R.P.M., maintains an average vacuum of 29 inches of mercury.

The third condenser is supplied by the Alberger Condenser Co. It is a surface condenser, with 2 passes of water, and has a cooling surface of 25,000 square feet, made up of 8,024 brass tubes, $\frac{3}{4}$ in. in diameter. Cooling water is supplied by two Alberger centri-

fugal pumps geared from a DeLaval Steam Turbine. The hot well pump is a single stage horizontal centrifugal pump driven by a motor.

Exciting current may be obtained from three sources; first, for starting, from a D. C. Generator driven by a Westinghouse Automatic Compound Engine; second, from either of two motor-generator sets, the motor taking its current from one of the machines then in operation. The third source is a number of storage batteries. These are used only when all other means fail.

The electrical equipment has also received careful attention. It is one of the finest that has been put in the new stations in this district. It comprises separate galleries for the D. C. switchboard, the A. C. board, the storage batteries, the oil-switches, etc. The operator on one gallery controls the high tension oil switches which are on another gallery, thus insuring his safety.

This general description will give the reader a few of the special features of this plant. As it is one of the first stations to produce power entirely from steam turbines, it will be interesting to engineers to follow closely its progress in erection and operation. Much credit is due the engineering staff for their courage and originality in carrying out this project under such exacting conditions.

A DISCUSSION OF VARIOUS METHODS OF CHARGING FOR ELECTRIC ENERGY.

E. Richards,

Electrical Engineer, Ontario Hydro-Electric Commission.

The method or methods of charging for electrical energy from hydro-electric or any other class of electrical plants is a matter of very great importance, whether the aim be to produce a maximum of profit from a given undertaking, or simply to assess the annual cost of an undertaking fairly upon all consumers supplied.

The following is an attempt to set forth briefly the various methods of charging, and their effects upon load factor and other features affecting the distribution of charges among various classes of consumers and the various consumers in a class.

The term load factor is rightly defined as the "average output by meter" divided by the "maximum demand," but it is sometimes taken as the "average output" divided by the "installed capacity."

(1) The flat rate based upon the installed capacity is doubtless the oldest and simplest method of charging for electric power, and for small plants with a small number of customers with high load factors it is fair alike to producer and consumer. Again, in many small plants the results obtained from other methods are not such as to warrant the increased expense and trouble connected with them.

The flat rate based on maximum demand throughout a given period of time is an advance over the above in some respects. It

allows the consumer much greater latitude as to the choice of motor capacity, without necessarily affecting the cost of power, to which he is justly entitled. Suppose, for instance, that a customer considers it advisable to instal a motor or lights, the capacity of which may greatly exceed his maximum demand for some considerable time in the future. He cannot justly be charged the same rate per H.P. of motor or light capacity as would be assessed upon another consumer whose maximum demand might even exceed his motor capacity. The main objection to the flat rate based on maximum demand is that it entails the taking of frequent power readings, or else the installation of a maximum demand meter with its attendant difficulties and expense. This difficulty might be met by installing a maximum demand meter where desired, and charging the cost of it to the consumer requesting such a service.

The amount of power that can be sold by flat rate from a plant of given capacity will depend upon the combined effect of the load factors of the individual customers and the tendency of the individual maximum demands to be coincident. Where the load factors of the various customers are low and where their maximum demands occur at various times of the day, it is evident that the maximum demand on the station will be much less than the numerical sum of the customers' maximum demands, and is generally a still greater amount less than the combined rated capacity of the customers' installations. In the case of commercial users of incandescent lighting this is not the case, because of the inherent tendency of the individual maximum demands to pile upon each other during one period, namely: 4.30 to 6 o'clock during the winter season. This fact is sufficient to largely account for the usual large divergence between the rates charged for electric light and for motor power.

(2) A rate per kilo-watt-hour based on the registration of an integrating watt-meter is the most widely used of all methods of charging. This is usually more or less fixed for light users, irrespective of capacity or consumption of energy, while for power users it is usually made to vary with the amount of energy consumed. This method approximates fairness only as the operating costs of the

plant, which are proportionate to output, become great relative to the fixed charges. It takes no account of load factor. For instance, a customer using a load steadily for 24 hours per day would have to pay 24 times as much as another who uses his maximum demand for the equivalent of one full hour per day only, while the former service might cost only slightly more than the latter. It takes no account of the time of use. The universal tendency of station loads to form peaks at certain definite times of the day and seasons of the year makes it inevitable that the idle capacity at other times of the day and seasons of the year can be disposed of at a profit at rates much below the normal to such consumers as can profitably utilize it.

(3) A rate per kilo-watt-hour by meter, with a minimum charge varying with the installed capacity, is a modification of the straight meter rate, and is a decided improvement in all cases where the fixed charges constitute any considerable portion of the total cost of power. It ensures that every consumer must at least pay a fixed small revenue per unit of installed capacity. Of course it has no equalizing effect outside its own range, and individual cases may and do arise where it may become somewhat of an injustice to the consumer. For instance: a large factory may wish to greatly divide its motor capacity with the expectation of securing increased economy, and thereby the load factor based on motor capacity may be greatly reduced, but at the same time the maximum demand may remain very much below the aggregate capacity of installed motors. In such a case the minimum charge based on installed capacity might often exceed the charge by meter, while the actual load factor would be quite satisfactory. In this case, as in part (1), there should be a provision whereby such a consumer could upon application have his minimum charge based on actual maximum demand instead of installed capacity. Fortunately this would be required only in the case of a comparatively large consumer to whom the cost of such a service would be insignificant.

(4) A meter rate based upon the equivalent hours' use at full capacity or upon the load factor, has many desirable features, especi-

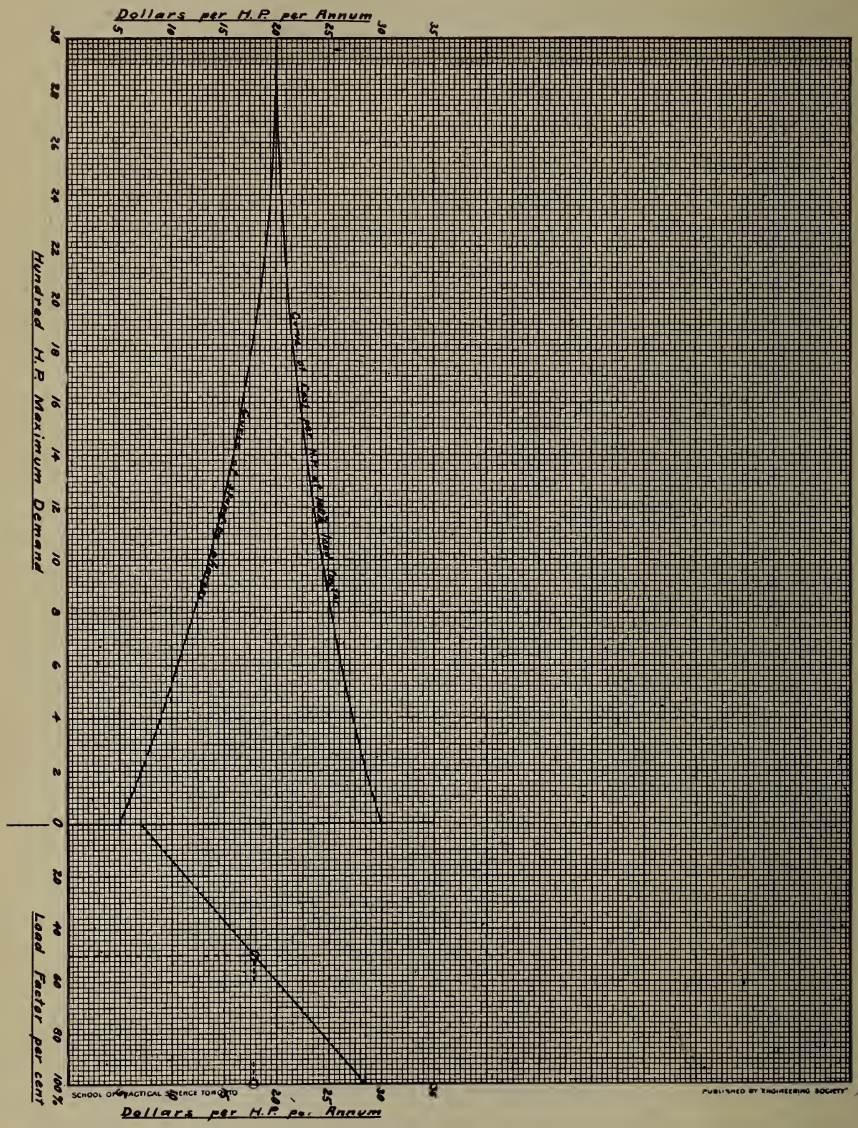
ally for the distribution of hydro-electric power. It recognizes the greater importance of load factor in preference to the minor consideration of increased cost of distribution to small consumers, and is therefore superior to any method previously mentioned. In Buffalo, where it is applied in the large business of the Buffalo General Electric Co., the rate per kilo-watt-hour varies with the ratio between the installed capacity and the metered input. The defect in the system as applied there is its failure to take cognizance of the often occurring difference between maximum demand and the total installed capacity. The rate could be made fairer for certain cases by being made to vary with the actual load factor. In one other unimportant respect it is deficient in that, as stated above, it fails to take into account the increased cost of distribution to small consumers over large ones, and in that respect it gives the small consumer an advantage over the large one, but it encourages the long hour use of light and power, and this strongly tends towards the filling up of the low portions of the station load curve.

(6) Two rate metering is accomplished by different methods, the most prominent of which is the installing of two meters, the shunt circuit of one of which is closed during certain peak hours by an electro-magnet whose circuit is closed and opened by a clock. There is therefore secured a double reading during certain peak hours. During these hours the customer would have to pay double the usual or minimum rate for such energy as might be consumed. The same result may be obtained by automatically or otherwise shunting the potential circuit of a watt-meter during all hours other than the peak ones mentioned above. By this means the consumer would pay only for a certain pre-arranged fraction of the maximum rate for all energy consumed apart from the peak hours. This method is probably one of the most effective means of influencing station-load factor. It can be made to penalize, as it were, the use of energy during certain limited hours, say from 4 to 6.30 p.m. for five months of the year, and at the same time encourage the use of energy at other hours and seasons. This method, combined with a system of variation of rates with load factor, constitutes what is

surely an ideal method of charging for electrical energy for lighting purposes. Of course it could also be applied to the sale of electric power, and would have, to a certain extent, the same effect as limited hour contracts for large motor users which have been found to be so effective in influencing load factor. It will be evident that in cases where sufficient limited hour motor contracts can be obtained to provide for the lighting peak there would not be any such great need of methods like two rate metering, and it would be a matter of choice as to which would prove the most effective.

(7) A stand-by charge of a fixed rate per h.p. to which is added a rate based upon meter registration is still another step in advance of all other methods previously mentioned for the sale of motor power. The stand-by charge may be based on the installed capacity or better still on the maximum demand, determined by frequent timing of the meter with a stop-watch or by the installation of a maximum demand meter. The meter rate is made to vary with the amount of energy used. This is the method adopted by the Cataract Power and Conduit Company in its distribution of Niagara Falls power at Buffalo. This method recognizes and can be made to adequately meet the following facts:—First, there are certain fixed charges which may be resolved into what is called the "stand-by" or "readiness-to-serve" charge; and second, there are certain charges which approximately vary with the energy used, and may be put into the form of a varying rate per kilo-watt-hour used. This system is of course very flexible, and may be made to seriously discriminate against the small consumer by making a wide difference between the maximum and minimum meter rates.

(8) For the sale of power the ideal system is one composed of a stand-by charge varying inversely with the maximum demand combined with a rate based upon the load factor. This system recognizes the fact which no other one does that the stand-by charge is less for a small consumer than for a large one. The method of applying this system will be explained by a reference to the accompanying diagram. For any given station capacity a diagram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is prepared where the base-line in the left-hand portion represents to any convenient scale the total capacity of the station, in this case 3,000 h.p. The cost of the output of the station at the station bus-bars is taken as one end of a probability curve (here $20 per h.p. per annum), and running through an arbitrarily chosen point, on the other side of the left-hand section, here taken as $5 per h.p. per annum. Theoretically it should pass through zero, but it is for convenience taken as a small quantity. This curve represents the readiness-to-serve charges per h.p. for customers with different maximum demands. The upper curve represents the cost of delivering power to customers of varying capacity from the full capacity of the station down to that of the smallest. To illustrate its application, take the following example: suppose a customer's maximum demand meter showed a maximum demand of 200 h.p. and his metered input for a given month of 30 days was 30,000 h.p. hours. Draw a vertical line through the 200 h.p., intersecting both curves; project horizontally the upper and lower points of intersection respectively to the right and left sides of the right-hand portion of the diagram; join the two points so found. Taking the point in this line above the load factor, which in this case was 50% on a ten-hour basis, shows a charge of $18 per h.p. on his maximum demand of 200 h.p.

This method, while ideal for motor users who are uncertain as to the time of their maximum demands, is not applicable to users of light and power the tendency of which is to concentrate at certain very restricted hours.

In practice the values of the stand-by charge corresponding to certain maximum demands would be shown in tabular form in the body of every contract. In another column would be shown the corresponding differences between the stand-by curve and the curve of 100% load factor cost. These quantities, it would be explained, would be multiplied by the load factor and added to the stand-by charge.

INTERIOR ELECTRIC ILLUMINATION.

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The question of interior illumination may be looked at from so many different points of view, is subject to so many influencing or controlling factors, many of which in any given case are generally not specifically determinate, and is so much a matter of personal taste, that no hard and fast rules can be given that will hold good under all circumstances. The utmost that can be done is to indicate the various results that it is generally desirable to obtain, the best methods of obtaining these results, and the fundamental principles governing the production and correct use of artificial light and its effect upon the human eye.

The point of view of the consumer, the man who pays for the light, is that it must be sufficient, of a suitable kind, generally pleasant to the eye, in some cases it must be novel or striking, and it must always cost him, both for installation and use, as small a sum as he can possibly obtain it for. It must also be safe and reliable and require a minimum of outside attention.

The lighting company's point of view is in most respects identical with that of the consumer. The consumer must be satisfied, his bills must be just and the service safe and reliable. In addition, it must be economical of operation and show a fair profit on the investment.

It is to the interest of the lighting company that the public be encouraged in and accustomed to liberal and unstinted use of artificial light. It is equally to the company's interest that this light

be used intelligently, with a minimum of waste and with a maximum of satisfactory results; and to this end it is extremely desirable that customers and prospective customers be advised as to the most appropriate and efficient methods of lighting their premises. The company's employees coming in contact with the customers, and particularly those soliciting new business, should be able to intelligently and concisely recommend the most desirable methods of lighting for any particular case, and should endeavor to so guide the customer, who of course will have the final decision in the matter, that the results obtained will give the best possible lighting consistent with the sum he is prepared to spend both for installing and use.

This paper will confine itself to a consideration of interior lighting by means of the electric current only, and I will assume that whatever methods of lighting are spoken of, the apparatus and service are each the best of their kind. This is an entirely reasonable and necessary assumption, and pre-supposes the following conditions: First, and most important of all, that the voltage supplied at the cutout is absolutely steady, except as affected by the operation of the customer's own lights. By absolutely steady, I mean that no sudden change in the consumption at another point of the system will be noticeable in the lights of the premises under consideration. Second, that variation in the voltage at the lamp is kept at as low a figure as is practicable; that the lamps, whether arc or incandescent, are of the correct voltage; that arc lamps are of the enclosed type and carefully trimmed and cleaned, and only the highest grade of soft carbons used therein; that incandescent lamps are maintained in good condition by systematic inspection and liberal free renewal, and that the entire consumption is on a meter basis; and finally, that on alternating circuits the frequency is not less than sixty cycles.

The human eye being adapted to working under the conditions existing in daylight, obviously the most desirable artificial lighting will be that which approaches most nearly to the natural. Hence we must take daylight, as we use it, or as we should use it, for interior lighting, as the guide for any attempt at a scientific and rational consideration of the subject.

The first question to be considered is that of intensity. The practical unit of light, the standard candle, though unsatisfactory in many respects, still is serviceable for making comparisons, and is in general use. The unit of intensity of illumination, the candle-foot, follows as a natural consequence. The candle-foot as a unit of illumination is that intensity of illumination obtained on a surface at a distance of one foot from a source of light having a power of one standard candle. If the light were emitted from a single point the intensity of illumination on a surface would vary inversely as the square of the distance from the point of light, and as the cosine of the angle of incidence. The light, however, never is emitted from a single point, and as will be seen later on, the application of the law of inverse squares cannot be relied upon as more than a useful guide for rough estimations. The angle of incidence need not, as a rule, be considered, since, when a brilliant illumination is required, as for reading, or the examination of goods, the surface may usually be placed at an angle of incidence whose cosine closely approaches unity.

A fundamental consideration affecting artificial lighting is the intensity of the luminous source, or the intrinsic brightness. By intrinsic brightness is meant the strength of light per unit area of light giving surface, the unit adopted being one candle power per square inch. The approximate intrinsic brilliancies in c.p. per square inch of some sources of light are given below.

Sun in zenith	600,000
Sun at 30 deg. elevation	500,000
Sun on horizon	2,000
Open arc light	10,000 to 100,000
Open arc light crater	200,000
Enclosed arc lamp with opalescent inner globe	75 to 100
Calcium light	5,000
Nernst "glower"	1,000
Incandescent lamp, clear	200 to 300

Incandescent lamp, frosted	2 to	5
Acetylene flame	75 to	100
Welsbach light	20 to	25
Kerosene light	4 to	8
Candle light	3 to	4
Gas light	3 to	8

The intrinsic brilliancies given for the sun at different positions in the meridian are, of course, the apparent brilliancies at the earth's surface. The actual brilliancy does not vary, the differences being due to the increased absorption of light by the atmosphere when the rays are nearly horizontal. A consideration of these differences brings up and illustrates a point in artificial lighting that is often overlooked, but yet is of primary importance in determining the amount of light required in any given case. One would hardly suppose that sun-light at midday was more than a hundred fold as intense as at sunset. Yet such is the case, and moreover when not in the direct rays of the sun, we can see to read almost equally well at any time of the day from sunrise to sunset. This shows that within a quite wide range of absolute brightness of illumination, our vision is about equally effective for all ordinary purposes. Provided the parts of the visual picture retain their relative brightness, the distinctness of detail does not vary materially with great changes of absolute brightness. This must not be construed as a statement that variation in intensity or unsteadiness is of little consequence. Sudden variations in intensity are extremely trying to the eye, and must by all means be avoided. It is, however, an enunciation of the principle that brilliancy of illumination has relatively less effect upon the eye than some other properties that will be considered later.

It will also be observed in the above table that there is a great difference in the intrinsic brilliancies of arc and incandescent lamps when with and without diffusing globes. This, of course, is due almost wholly to the immensely greater radiating surface of the globe over the carbon arc or filament, and illustrates the importance

of having as great an area as possible from which the source of light may distribute its rays. In a room lighted by daylight, the source of light becomes practically the whole surface of the window panes. A well lighted office will have windows whose light emitting area is equal to not less than about one-eighth of the floor area. Yet the projected surface of an outer arc lamp globe seldom exceeds one square foot. The projected surface of a frosted 16 c.p. lamp is about six square inches, both of which areas are out of all proportion to the surfaces to be lighted.

If the radiating surface be not thus distributed, every time the eye catches a direct ray, an after image will be formed upon the retina, fatiguing it, and causing the pupil to contract. When the eye then looks away from the lamp, the reflected light appears dim owing to this contraction, and the room seems to be insufficiently lighted, when quite the reverse may actually be the case. This contraction and enlargement of the pupil is the cause of annoyance in flickering or unsteady light.

Hence to approach the conditions of daylight, the enclosing globes for interior lighting must be of translucent material, and these globes should have as great a light emitting surface as mechanical considerations and artistic effect will allow. The question as to how much light is cut off by such globes will be taken up further on.

Now as to color. It is generally desirable that artificial light shall have the color values of diffused daylight, this white light being the one to which the eye is accustomed and adapted. This is particularly necessary in stores where certain kinds of dress-goods, carpets and furniture are sold, in textile mills and picture galleries, and wherever colors are to be matched or closely examined. In certain other cases, however, such as in domestic illumination, a light slightly richer in yellow and of softer tones, may be preferred. Except for scenic effects, a preponderance of any other color than yellow should be studiously avoided, for not only does such an excess injure color perception, but the luminosity of such rays compared with that of yellow is low.

The general effect of colored lights is to accentuate objects of the same color as the light, and to change or dim all others. The following table given by Dr. Louis Bell, shows the effects resulting from lights of different colors falling upon differently colored fabrics. The fabric colors are the ordinary commercial pigments. Thus a blue light falling upon a pigment yellow fabric will show green. Falling upon a light blue, it will show the fabric as a very vivid blue. An ordinary white object will appear of the same color as the light falling upon it.

We have to deal with white light tinted with other colors as a rule, so that generally the effects will not be as marked as is indicated in the table.

Arc lights vary very much in color, from a clear white in short arcs to a bluish white or violet in long ones. Incandescent lamps, if worked at low efficiency, are yellow, and become more and more nearly white as the efficiency increases. For this reason, if for no other, lamps with an efficiency lower than 3.8 or 4 watts per candle are undesirable. From the point of view of the color of the light emitted, the greater the efficiency above this minimum the better, as the limiting efficiency due to the lamp life will be reached before that due to the intensity.

These considerations of color divide interior lighting into two separate classes, namely, those cases in which white light is necessary or preferable, and those cases in which such a light is not necessary or is even undesirable. In general terms, it may be said that the arc light should be used in the first case, and the incandescent in the second. When we come to consider the question of distribution and arrangement of light, it will be found that interior lighting is again divided into two classes: one, more appropriate to the arc light and the other to the incandescent, and it will further be found that these two divisions very nearly coincide. That is to say, in any given case, where arc lighting is preferable from a color point of view, arc lighting will generally be preferable from considerations of light distribution and arrangement.

Original Color of Fabric.	Color of Light Falling upon Fabrics.					
	Red.	Orange.	Yellow.	Green.	Blue.	Violet.
Black	Purplish-Black.	Deep Maroon.	Yellow-Olive..	Greenish-Brown.	Blue-Black...	Faint Violet-Black.
White	Red	Orange	Light Yellow.	Green	Blue	Violet.
Red	Intense Red.	Scarlet	Orange	Brown	Violet	Red - Violet - Purple.
Orange	Orange-Red..	Intense Orange.	Yellow-Orange.	Faint Yellow, slightly Greenish.	Brown, slightly Violet	Light Red.
Yellow	Orange	Yellow-Orange.	Orange-Yellow.	Yellowish-Green.	Green	Brown tinged with faint Red.
Light Green	Reddish-Gray	Yellow-Green	Greenish-Yellow.	Intenser Green.	Blue-Green...	Light Purple.
Deep Green	Reddish-Black.	Rusty-Green..	Yellowish-Green.	Intenser Green.	Greenish-Blue.	
Light Blue	Violet	Orange-Gray..	Yellowish-Green.	Green-Blue ..	Vivid Blue ..	
Deep Blue	.....	Gray, slightly on Orange.	Green-Slate..	Blue-Green ..	Intenser Blue.	Bright Blue-Violet.
Indigo Blue	.....	Orange-Maroon.	Orange-Yellow (very dull)..	Dull Green...	Dark Blue-Indigo.	Deep Blue - Violet.
Violet	Purple	Red-Maroon...	Yellow-Maroon.	Bluish-Green-Brown.	Deep Bluish-Violet.	Deep Violet.

The relation of reflection and diffusion to practical illumination is of great importance, and must be carefully considered for each individual case. The underlying principles may be easily stated, but it is often difficult to so apply them as to obtain satisfactory results.

Regular reflection, when the incidental reflected rays lie in the same plane, such as occurs from mirrors and highly polished metal surfaces, is generally a simple matter so far as direction is concerned, but diffuse reflection is of a much more complicated character, and it is that kind with which we usually have to deal.

In diffuse reflection, the light is reflected irregularly in every direction owing to the roughness of the reflecting surface. If the surface be a comparatively smooth one, as for instance a painted wall or ceiling, or some grades of wall paper, the reflection will be both regular and diffuse, there being a general predominant direction of reflection, plus a certain amount of diffuse reflection. This condition is the one that usually obtains in interior lighting.

If the reflecting surface be colored, the reflected light will of course be colored or tinged. The more minute the roughness of the surface, the greater will be the selective reflection, and hence the greater the coloration of the light, owing to the selective or cumulative effect of each successive reflection. This coloration of the light, owing to reflection, is generally greater, and has more effect upon the eye than the original color or the light itself, and unfortunately these two colorations cannot, as a rule, be made to neutralize one another, so that in planning the general color tone of a room to be illuminated, it must be remembered that if the walls are strongly colored, the dominant tone of the illumination will be that of the walls rather than that of the light.

There is an actual loss of light with every reflection, due to absorption by the reflecting surface. In direct reflection, this loss varies greatly with the angle of incidence, the total loss being from ten to seventy per cent. for highly polished surfaces. In diffuse reflection, the loss depends very little upon the angle of incidence, but greatly upon the nature of the surface and upon its color. The

more minute the irregularities of the surface, the greater will be the selective reflection, as stated before, and the greater the loss. The darker the color, the greater will be the loss, owing to the greater absorption of the yellow and orange rays.

Hence the color and character of the reflecting surface affect the total quantity of the useful light. A table showing the relative values of some reflecting surfaces, mostly paper, is given below.

DIFFUSE REFLECTION.

Material.	Coefficient of Diffuse Reflection. K	$\left(\frac{1}{1-K}\right)$
White Blotting Paper	.82	5.56
Chrome Yellow Paper	.62	2.63
Orange Paper	.50	2.00
Clean White Pine	.45	1.82
Yellow Paper	.40	1.67
Light Pink Paper	.36	1.56
Light Blue Paper	.25	1.33
Light Brown Paper	.20	1.25
Green Paper	.18	1.22
Dark Brown Paper	.13	1.15
Vermilion Paper	.12	1.13
Dark Blue Paper	.12	1.13
Black Paper	.05	1.05
Black Cloth	.012	1.01

It will be seen from this table that the lighter the color of the surface the higher the coefficient of reflection. The rough fibrous wall paper now popular also has a high coefficient.

Now the effective illumination at any point in a room will be the sum of the direct and reflected lights. The reflected light will be composed of some light reflected once, a smaller part reflected a second time, a still smaller part reflected a third time and so on, each additional reflection reducing the amount in the proportion of

the coefficient of reflection. Expressing this concretely, if L be the light received directly the total light received will be $L + KL + K^2 L + K^3 L$ and so on where K is the coefficient of reflection. This series approaches the limiting value $L\frac{1}{1-K}$ as the number of terms is indefinitely increased. The expression $\frac{1}{1-K}$ is the factor by which the direct light at a point must be multiplied to obtain the total light there. This will always exceed unity. Its value for average conditions will probably be between 1.25 and 2.00.

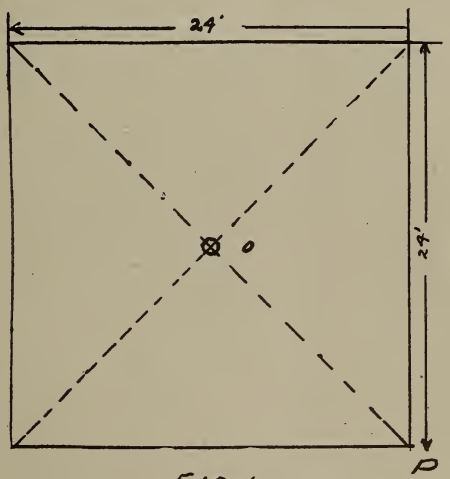


FIG. 1

In applying these principles to practical illumination, let us first take a simple concrete case. Assume a room 24′ x 24′, Fig. 1, to be lighted sufficiently that one may easily read in any part of the room. Let the walls and ceiling have an average diffusive coefficient of .34, which will make $\frac{1}{1-K} = 1.51$, say 1.5, increasing the effective value of the radiant by 50 per cent. Let the light be 8′ above the floor, and assume that the plane to be illuminated is 3′ above the floor. A good light to read by would be one candle foot. Take first the case of a single light in the centre of the room at the point

O, Fig 1. The greatest distance from O to a corner P of the plane is 17.7′, which would require that the light have a power of $(17.7)^2$ or 313 candles if there be no reflection from the walls, etc. With the reflection assumed, the light must be $\frac{1}{1.5} \times 313 = 207$ c.p., say 13 sixteen c.p. lamps. Such an arrangement would be absurd. The centre of the room would be so brightly illuminated that the walls and corners, though actually well lighted, would appear dim by contrast. Let us try dividing the light into four clusters, *a*, *b*, *c*, *d*, Fig. 2. Then to light the same corner P with the minimum of one

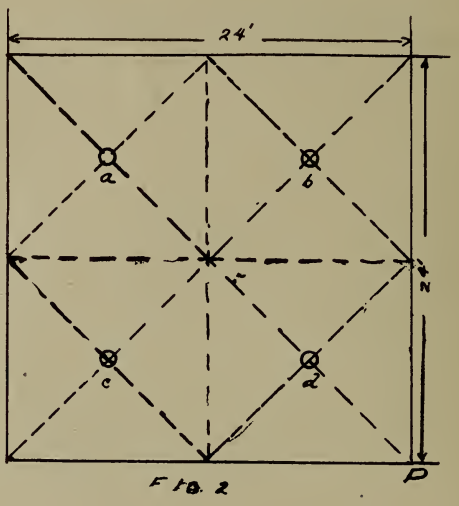


FIG. 2

candle foot, we must figure the distances of each illuminant, *a*, *b*, *c*, *d*. These are 25.9′, 15.7′, 15.7′, and 13′ respectively, and for each candle power at these points the light received at P will be $\left\{\frac{1}{(25.9)^2} + \frac{1}{(15.7)^2} + \frac{1}{(15.7)^2} + \frac{1}{(13)^2}\right\} \times 1.5 = .0233$ c.p. Hence to obtain one candle foot at P, each of the lights *a*, *b*, *c*, *d* must be of 42.9 c.p., or 172 c.p. altogether, against 207 in the first case. This is a great improvement, not only in economy, but also in results, for whereas the maximum illumination on the reading plane in the first case was

12.5 candle feet, the maximum in the second case is only about 3.5 candle feet.

Placing five lights as shown in Fig. 3, each would have to be of about 29.2 c.p., and the maximum illumination on the reading plane would be about 3.1 candle feet under the centre light. That is to say, five 32 c.p. lamps arranged as in Fig. 3 give better illuminating results than thirteen 16's clustered in the centre of the room.

Obviously then, with a fixed minimum illumination, the greater the distribution of the illuminants the greater the economy and the better the lighting, and this general principle is applicable for all

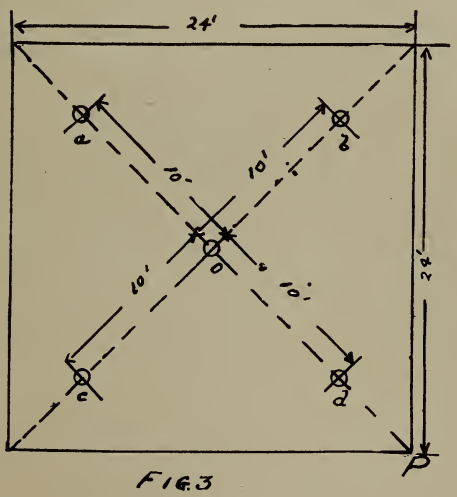


FIG. 3

classes of interiors. There will be many modifying circumstances, such as the necessity of additional brilliancy at certain points, the fact that the corners of rooms need seldom have the light required even for general illumination, the shape of the interiors, and location of furniture, machinery, belts, pillars or other shadow casting objects, and finally the location of doors, windows, pictures or other objects affecting the wall diffusion.

This division of the illuminants must not be carried too far, as the total abolition of all shadow is undesirable, especially in domestic

lighting. Such a condition produces a flat appearance in the room that is very trying to the eyes. Generally speaking, however, the number of divisions of the light will be limited by the size of the units economically desirable and by the cost of installation. It is not desirable to have 110 volt incandescent lamps of less than 6 or 8 c.p.

For domestic lighting it is not so necessary that the results shall nearly simulate daylight, either as to intensity or distribution. It will give an equally good effect and at a lower cost if only a very moderate general illumination be provided, adding to this whatever additional light is required for special purposes. The controlling feature in domestic lighting is generally the artistic effect desired, and this confines us to the use of either chandeliers or side brackets, or in some cases to ceiling lights. Drop lights, either suspended by cords or by rods, are not desirable. Portable drop lights, however, are very efficient where such lighting is appropriate, and their use should be encouraged. Side brackets generally give a better distribution of light than do chandeliers even in small rooms, and they also are more easily placed so that the light falls just where it is most required. They should not be placed too low, however, which I think there is generally a tendency to do. Both brackets and chandeliers should have widely extended arms, and the lights should preferably be so held as to point downwards.

The height at which lights should be placed will depend upon the height and character of the room, the diffusive power of the walls and ceiling, the strength of the lights and the strength of the light required on the lighted surface, and the height of the latter. It is usual to assume the height of the illuminated plane as $2\frac{1}{2}$ or 3 feet above the floor. Of course, incandescent lights, not controlled by wall switches, must be within convenient reach, which requires that the sockets be at a height of not more than six feet in residences, and seven feet in stores and offices. This brings the light lower than it is generally desirable. The lower the light the greater the direct illumination, but the higher it is placed, the greater the diffused illumination, and above all, the higher the light the less will be the liability of direct radiation to the eye. This must

be avoided by all means, even if the lamps have to be placed so high as to sacrifice considerable light. A much better general effect will be produced if the lights be high up, especially in large interiors where the eye is more liable to catch direct rays. For such cases, some authorities give the correct height as about .6 times the distance between lights.

I think that it is better to consider each interior independently, placing the lights on wall switches as high as the desired intensity of illumination will allow, and those controlled by socket switches, as high as the socket can be conveniently reached.

As to the use of shades and reflectors in domestic lighting, their importance is largely dependent upon the conditions. For drop lights, where the walls and especially the ceilings are finished in a light color, I do not think that flat reflectors either increase or improve the light to any extent. One is so accustomed to seeing a shade of some kind, however, that the lamp looks incomplete without one, so that a shade or reflector of some kind should invariably be used. With darkly colored walls and ceilings, flat reflectors are of great assistance in increasing the lighting, to such an extent indeed, that when used under such conditions the coefficient of diffuse reflection of the reflector is of more importance than that of the walls and ceiling. The white porcelain shade gives the best results, and the best size to use will depend on the height of the lamp, the object being to deflect the light rays that would otherwise reach the ceiling and upper parts of the walls. The absorption of these reflectors seems to be about 13 per cent. The fluted shade gives a slightly better light diffusion than the smooth, but is more difficult to keep clean. Mirror reflectors should be avoided in domestic lighting.

All lights, other than drop lights or ceiling lights, should be shaded by some form of bell shade or by an outer globe. The best of all from light distributing point of view are the holophane, and their use should be recommended. Next to these come the translucent poreclain and ground or etched glass. Cut glass is of little use, as are all colored glass shades or globes, and those casting a streaked or mottled shadow should be especially avoided.

The primary requirement of shades and globes is that they shall soften and diffuse the light. They do this, of course, at the expense of some light, so that all calculations must take into account this loss. Many tables have been given showing the loss, but they vary between pretty wide limits, very much depending upon the thickness of the shade and the character of its surface. The following table may be used for average conditions:

Material.	*Per Cent. Loss.*
Clear Glass	10
Alabaster Glass	15
Ground Glass, Light Grinding	15-20
Ground Glass, Heavy Grinding	25
Light Opal Glass	25-40
Heavy Opal Glass	40-60

It must always be remembered that, though the use of shades and globes reduces the total light, the resulting diffusion and lessening of the intrinsic brilliancy more than compensates therefor. That is to say, a room, part of whose light is cut off by properly arranged shades, will appear better lighted than if the whole light were employed unshaded.

The whole subject hinges upon the fact that the eye will adjust itself to the maximum intensity of illumination, adjusting the admission of light to the retina to that maximum, so that every other part of the field of vision appears dim owing to the contracted state of the pupil.

The use of ground glass or frosted incandescent lamp bulbs should be much greater than it is. Personally, I think that every light not shaded by a globe or deep bell shade should be frosted, and that even when so shaded it should be frosted if the lamp bulbs can be seen from any part of the room as ordinarily occupied. To this end, the incandescent lamp department should be equipped with the simple apparatus and few chemicals necessary for frosting the lamps as received from the manufacturer, reserving only a few clear glass

lamps for use in special cases, as when the lamp is enclosed in an outer globe. I think that the frosted lamp should be regarded as "standard," and always supplied to customers, excepting when clear glass is specifically called for. The lamps might be given two different degrees of frosting, a light one for those to be used with bell shades, and a heavy one for those to be used with flat shades. In any case the amount of frosting should always be uniform. The light cut off by this frosting varies between about three and seven per cent.

The actual amount of light required for residence lighting can be given in candle feet with a fair degree of accuracy, but to give it in watts per square feet or even in number of square feet per incandescent lamp involves the questions of reflection, distribution and loss of light above considered, besides that of lamp efficiency.

I think that the following figures in candle feet will give good lighting effects. The column marked square feet per 16 c.p. lamp, and watts per square foot, can only be regarded as approximate, and are figured on the assumption that the lights are as fairly well distributed as is ordinarily possible in domestic lighting, that they are shaded by efficient shades, are frosted, and are 56 watt lamps.

It might be objected that the difference between the light required for rooms having light or dark colored walls is not so great as the previous emphasis of the advantages of light colored walls seemed to indicate. The table, however, was compiled on the assumption that the shades were so selected as to deflect much of the horizontal light downwards. Nevertheless, reflection and diffusion by shades can never equal, in good effect, that of light colored walls and ceilings.

I think that the best way to consider the subject is to assume the candle feet required in a given case, and from that deduce the lamps required to give that illumination, taking into consideration all of the above controlling facts and allowing a liberal margin for loss in reflection due to the discoloration of walls and shades, and for deterioration of the lamps.

	Candle Ft. for Gen. Illum.	Sq. Ft. per 16 c.p. Lp.		Watts per Sq. Ft.		Notes.
		Light Walls and Hangings.	Dark Walls and Hangings.	Light Walls and Hangings.	Dark Walls and Hangings.	
Halls	.5	120	90	.47	.62	
Dining Rooms	1.0	60	45	.93	1.24	Main light over centre of centre table; side lights for side tables if necessary.
Reception Rooms	1.5	45	30	1.24	1.87	Brackets or wide armed chandeliers, preferably 8 c.p.
Bed Rooms	.75	84	60	.67	.93	Side brackets at convenient points.
Library	1.0	60	45	.92	1.24	Side brackets with portables.
Sitting Rooms	1.0	65	45	.86	1.24	

There are certain cases when a single source of light may be preferred by the customer, even in fairly large interiors, as over the centre of a dining-room table, or in a square hall. Here a single 16 c.p. or 32 c.p. lamp may be employed, placing it as high up as possible, and enclosing it in a ground glass globe. These single lights will be powerful enough only for very small rooms. For larger rooms the meridian lamp may be substituted, and produces a very pleasing effect when placed well above the line of vision. For large interiors of every kind, where a unit larger than the ordinary incandescent is desired, these lamps are very serviceable.

General office lighting partakes somewhat of the character of domestic lighting in that as a rule the units required are small, and there is considerable assistance from wall and ceiling reflection. The illumination, however, must be greater. It should not fall below one candle foot for general illumination, and the customer may require as much as four candle feet at particular points, but this should be discouraged. Three candle feet seems to be the maximum desirable intensity for such lighting. Large offices may use enclosed arc lamps with very satisfactory results, but these will often give more intense illumination than is desirable, when Nernst or Meridian lamps may be substituted.

Nernst lamps have a high efficiency as compared with the ordinary incandescent, about two watts per spherical c.p., but are not as yet available for all circuits. The two and three glower lamps seem to give good results where 220 volt. A. C. is used, but for larger units the arc lamp is to be preferred. I think that one reason why the Nernst and Meridian lamps are so well liked is that the lamps and globes themselves are graceful and simple in outline and are designed to give a maximum of diffusion and reflection.

The lighting of small stores is generally the most unsatisfactory of all. This is often in part due to the merchant not renewing his lamps when required, or keeping the bulbs and shades clean. It is still more often due to improper arrangement and insufficient number of lights. The conditions require abundant light to give good

results, and it is in just these places that economy is most necessary. Very many of these small stores look dingy when lighted even by a liberal number of incandescent lamps, owing to the yellowness of the light and the generally dark and mixed character of the surroundings. The remedy is to replace the small incandescents by small arc lamps or Nernst lamps taking the same power, placing them high up and using efficient diffusing shades. At the same time the merchant should be induced to so arrange his goods as not to obstruct the light, and in small dry goods stores he will get better lighting if he will line the walls with light goods and place the dark ones upon the tables. The general illumination for these stores should not fall below one candle foot, which will usually require one 16 c.p. lamp for about every 50 or 60 sq. ft. But better results may be obtained by using one arc lamp where from 6 to 10 lights are required, if the shape of the room lends itself to effectual lighting from a single source.

Large stores are generally more easily lighted than small ones. They are conveniently divided into sections by the arrangement of the pillars and passageways and the ceilings are higher, and in modern buildings are almost invariably painted white, or are given a very light tint. Here the arc lamp seems to be entirely suitable. The lamps should be hung in the aisle centres or on the centre lines of counters, equidistant and at a uniform height. The most effective height seems to be about 9 feet, though this will depend somewhat on the illumination desired. The conditions being, comparatively speaking, constant, the amount of light required can be much more accurately estimated than in the case of small stores. Each 500 watt arc lamp should light a space of from 400 to 600 sq. ft., depending upon the character of the goods, or from 1.25 to about .8 watts per sq. ft. The general tendency is to give too bright an illumination. In several large stores that I have examined the watts per sq. ft. ranged from 1.5 to 2.0. The result was an unnecessarily bright light that was trying to the eyes. Mr. W. D. Ryan recommends from .75 to 1.5 watts per sq. ft., even falling as low as .5 in some cases. Unfortunately the distance between aisle centres is, as a

rule, not more than 16 or 18 feet, so that it is often difficult to so arrange the lights that there will not be light and dark spots. A good point to remember is that an endeavor should be made to have the bright spots fall upon the counters and goods, and the dark spots upon the wide aisles. But this must not be done by hanging the lamps out of line with one another.

The size of the lamps need not necessarily be the same in every case. It is better to adjust the size of the lamp to the light required than to burn too large or too small a lamp merely because that size

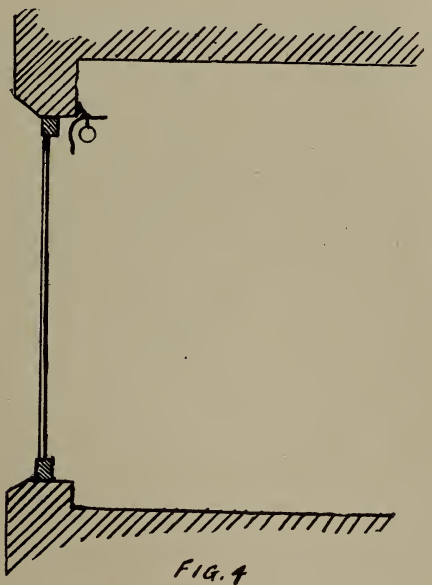


FIG. 4

has been adopted as standard, even though this multiplication of sizes will entail additional work in the storeroom. Where the lighting company can control or influence the selection of lamps, three or at least two different sizes should be used.

The figures of watt consumption per sq. ft. given above should determine the size of lamp to be used in any given case, when the general arrangement of the aisles or pillars fixes the number and location of the lamps.

Arc lamps should be operated on 110 volt. circuits in preference to the 220, owing to the extremely blue color of the high voltage arc, and each should have a conveniently placed switch to allow of individual operation.

In the lighting of store windows the brightest light of all is required. This light should come from the front of the window, the lamps being placed so high up and near the glass that they are invisible from the street. This is easily obtained with incandescent lamps by placing a row of lamps in a trough-shaped metal reflector as shown in Fig. 4. For large and high windows the 16 c.p. lamps should be spaced about 15 inches apart for light goods, and about 12 inches for dark goods. Small windows will require lamps about 18 inches apart. The bulbs should not be frosted.

I do not think that rows of lamps arranged on the sides or bottom of the window give effective lighting in any case, or that any other system can equal in effect that of placing a single row of lamps as shown. Unfortunately the window lighting for many stores requires to be of as white a color as that required for the interior, so that the merchant should, if possible, be induced to use small arc or Nernst lamps in his windows in such cases. If an efficient form of reflector be used, a single small arc lamp, taking power equivalent to about six incandescents, will light a medium-sized window very effectively, the lamps being still placed high up near the front of the window, and if necessary, shielded from view from the street by a metal reflector.

Two or three Nernst lamps will give still better results.

In shop and mill lighting the conditions are not so rigorous as in stores, in that the lamps may generally be placed at the exact location desired. But the diffusing value of the surroundings is lower. Arc lamps are preferable to incandescents and are more economical if the interior be large and with high ceilings.

The following table, collected from a number of installations, gives the approximate floor area that should be allowed for various

classes of shops and mills using 5 ampere lamps with efficient shades and reflectors:

Building.	*Sq. Ft. per 5 Amp. Lamp.*
Machine shops with high roofs, large machines and many belts	400
Machine shops with low roofs, large machines and many belts	500
Machine shops with few obstructions	650
Textile mills with high looms, white goods	420
Textile mills with high looms, colored goods	380
Textile mills with low looms, white goods	450
Textile mills with low looms, colored goods	400

These figures are on the assumption that a good light is required in every part of the room. In large machine shops and erecting shops such a light will be required at certain points only. Incandescent lamps may be used at these points, and the general illumination reduced to about one arc lamp for about 1,000 or 1,200 sq. ft. Reflectors should be used in all cases.

These general statements as to interior lighting may be summarized as follows:

The intrinsic brilliancy of the source of light should be as low as possible, which will be most readily obtained by enclosing the light in translucent globes. The light should be evenly distributed, which is best obtained by using many small units. It should be well diffused by light colored walls and ceilings, and by efficient reflectors. It should be kept out of the line of vision by placing the lamps as high up as circumstances will allow. It should be of suitable color, and finally the lamp or fixture and shade, unless intrinsically ornamental, had better be severely plain and as inconspicuous as possible.

SOME FEATURES OF MODERN CORLISS ENGINES.

A. K. Spotton, '94.

The fact that the direct-connected electrical generator has almost entirely superseded the belt-driven type which was at first used for light and power purposes, has led to radical changes in the design of the engines employed.

Commercial considerations have always considerable influence in determining the purchase of a machine, and with the keen competition in this line of machinery, has come the tendency of electrical companies to offer generators of as high a speed as was conformable with first class economy in the engines. These circumstances have forced the engine builders to construct four valve automatic cut-off engines, mainly of the "Corliss" type, running from 125 to 175 revolutions per minute, the usual speed being 150 revolutions per minute. The old familiar type of Corliss valve gear with its long rock arms, heavy wrist plates and vacuum dash pots of uncertain action has been abandoned for a system with moving parts of less inertia, and a positive quick-acting cut-off. As is bound to be the case, designers differ as to the best methods of obtaining these ends, and the result has been the development of two types differing mainly in the method of governing the cut-off.

The first of these is provided with a shaft governor directly connected to the steam valves through a wrist plate motion, the valve travel and opening being varied by shifting the eccentric in a manner similar to high speed engines of the familiar type. The chief disadvantage of this system is the fact that the friction load of the valve gear has considerable effect on the governor, and as

the valves are unbalanced the regularity of the governor is dependent to a large extent on the efficiency of the oiling system, and thus an element of much uncertainty is introduced. Another draw-

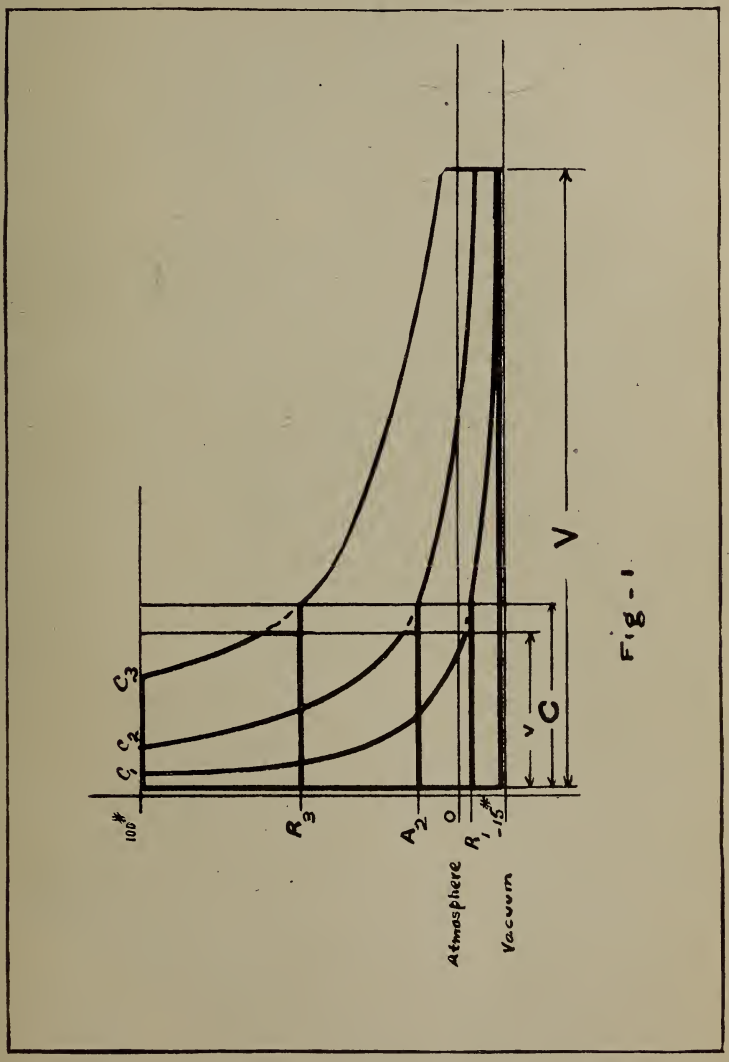


Fig - 1

back is the great weight required in a governor of this type to successfully control the cut-off on both cylinders of a compound engine,

and it has been the practice of some builders to put a fixed cut-off corresponding to the rated load of the engine on the low pressure cylinder. This condition is permissible in an engine which is carrying a practically steady load somewhere near its rated capacity, but when the load is a widely varying one and particularly when it is carried by two or more engines driving alternating current generators running in parallel, the detrimental effect of this method of governing becomes apparent. Figure 1 shows the combined cards of a compound variable cut-off engine.

V and v represent the volumes of low and high pressure cylinders respectively. C_1, C_2, and C_3, the points of cut-off in high pressure cylinder corresponding to respectively a light load, rated load and overload. C is the constant cut-off in the low pressure cylinder. R_1, R_2, and R_3 are the receiver pressures corresponding to these points of cut-off. It will thus be seen that as the load goes off, the receiver pressure drops and the high pressure cylinder carries the greater portion of the load. As the load increases beyond the rated capacity of the engine the reverse conditions exist and at nowhere except the rated load is the load evenly divided between the two cylinders. The conditions of driving alternators in parallel require that impulses given to the cranks be as even as possible, and the overload capacity demanded in modern electrical plants is 50%, so that to get the best results the cut-off on both cylinders should be controlled by the governor. This, in the other type of high speed Corliss engine, is accomplished in the usual way by employing a trip motion and controlling the period of unhooking by a governor of the flyball or inertia type. A single cylinder engine of this style is shown in Fig. 2. The absence of wrist plates and the general lightness of the moving parts is noticeable. The closing of the valves is accomplished by steam pressure, which acts on a small plunger to which the valve arm is attached. There is also provided an air cushion which allows the valve to come to rest gently after the point of closure. This arrangement gives an extremely rapid and positive cut off, permitting a high speed of rotation. In the modern Corliss engine much care is given to the manufacture

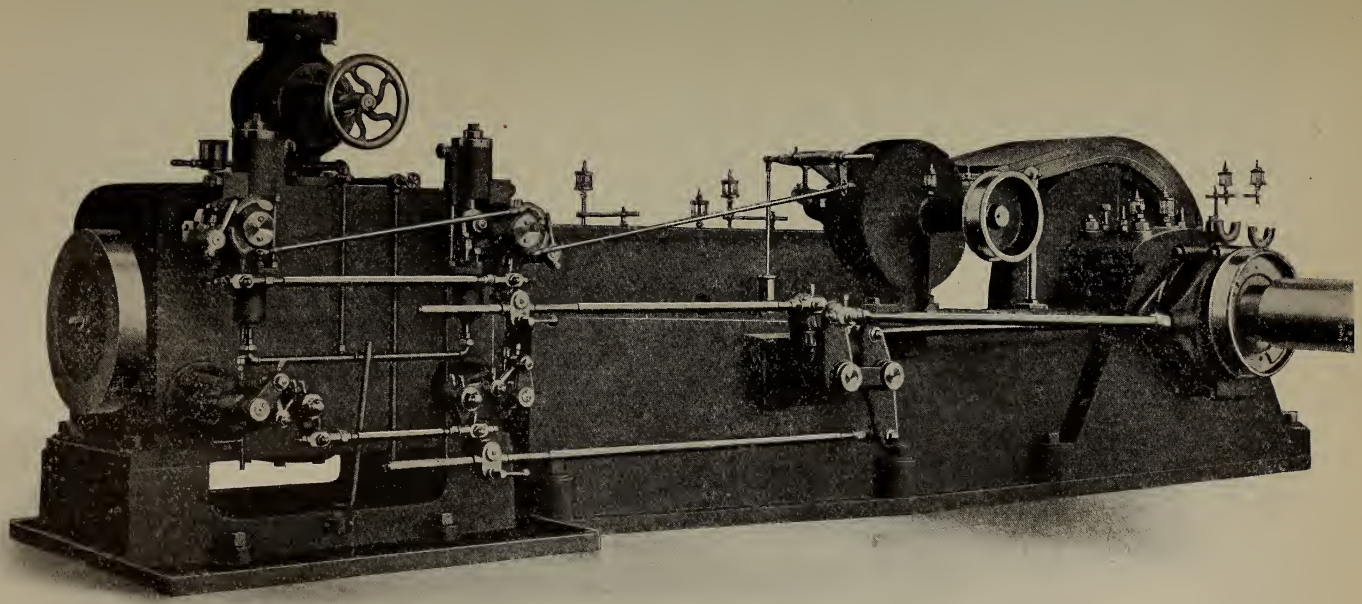


FIG. 2.

of the valves and their seats. The laborious method of scraping the valve and its seat to a steam-tight fit has been superseded by lapping the seat out with a lead lap and emery, which gives a perfect bearing seat. The valve is ground to gauge in a grinder to suit the seat, and a steam-tight valve is assured without the need of any hand fitting. Some makers furnish ground seats which are pressed into the cylinder casting and when worn can be removed and replaced by new ones. The frame is a radical departure from the type long associated with the Corliss engine, and commonly known as the "Girder" frame. As steam pressures and speeds of rotation increased, a point was reached at which this type of frame was wholly inadequate. It was hence replaced by a frame in which the pillow block end was very massive and connected to the cylinder by the circular guide casting. This has in turn given place to a frame cast in one piece and resting on the foundation for its entire length. This frame is fitted with a main bearing with side wedge adjustment, and of such a size that the pressure per square inch of projected area does not exceed 130 pounds. For direct connected engines running alternators in parallel with their heavy fly wheels and generator rotors, this consideration results in extremely large bearings which are usually provided with water cooling pipes attached to their lower shells. Attempts have been made to give these bearings a vertical wedge adjustment, but this was found to be unsatisfactory, and any wear of the main bearings is allowed for by a layer of thin shims placed between the generator housing and its bed plate, and which may be removed as the shaft goes down. The cylinders are lagged with a non-conducting material covered by sheet metal. Steam jacketting has been generally abandoned except in special cases, although some makers still jacket the heads. This somewhat lowers the steam consumption, but with the use of superheated steam the advantage of jacketting is a doubtful quantity. The crank and crosshead pins have been materially increased in size, and in the better makes of engines they are made of steel which is case-hardened and ground, giving a surface which ensures cool running. This matter of pin surface has a very important bearing on the running qualities of the engine,

and with a properly hardened and ground pin it is possible to run cool a pin whose dimensions are much smaller than modern practice dictates. A greater pressure than 1,200 pds. per square inch of projected area on the crank pin is not considered good practice, yet a well ground, hardened, and properly set pin has been known to run many years with no trouble subjected to nearly double this pressure.

The oiling of an engine of this type is of great moment, and too much care cannot be taken to see that all wearing parts are furnished with a copious supply of oil. The usual procedure is to employ an automatic oiling system which supplies the oil to the engine through a system of pipes under pressure. This pressure is obtained either directly from the oil pump or from a tank raised above the level of the engine oil cups. The latter method is preferable as it maintains a constant pressure without complicating the system. The oil flows by gravity from the tank to the oil cups, which are of special design to stand the pressure put on them, and are of the sight feed type. They also are provided with an oil reservoir and can be used as ordinary sight feed cups, should anything happen to prevent the pressure system from working. From the cups the oil is all collected and discharged into a filter under the floor of the engine room and from there is pumped back to the tank. With this free delivery of oil and high speed of rotation, there is a great liability of having the oil thrown over the engine and floor, and to prevent this it has become the custom to enclose the crank and eccentrics more or less completely with sheet metal shields which effectually prevent this throwing of oil. So important has this matter become that the making of these sheet metal shields alone has become a business of magnitude.

In making out a specification for a direct connected engine on which a manufacturer may tender, the following information should be furnished by the engineer:—Capacity of generator; number of revolutions per minute; steam pressure carried on boilers; whether engine is to be single cylinder, cross compound or tandem compound; whether engine is to run condensing or non-condensing; the

probable back pressure if the exhaust is to be used for heating, drying or other similar purposes; whether generator is direct current or alternating; if the latter, number of cycles and phases.

The above information is necessary for a manufacturer to intelligently tender on an engine for a given service with a view to getting the best results. When this information has been given the following clauses should be inserted in the specifications as they enumerate qualities which are essential to a first class Corliss engine of the high speed type.

Valves and Seats.—The valve seats if circular are to be ground out and the valves ground to suit, ensuring a steam-tight joint without hand fitting.

Frame.—The crosshead guides and main bearing parts of the frame are to be cast in one piece and the frame is to rest on the foundation for practically its whole length.

Governor.—The governor is to have control of the cut-off on both high and low pressure cylinders, and when driving alternating current generators in parallel, the momentary variation caused by throwing on or off the entire rated load shall not exceed three per cent. of the mean speed of the engine.

Crank and Crosshead Pins.—These pins are to be of steel and are to be case-hardened and ground to a true surface, and are to be inserted in the crank at perfect right angles in all directions to the centre line of the engine.

Oiling System.—The engine shall be provided with an automatic oiling system which shall feed oil under pressure to all bearings.

TYPICAL EUROPEAN LOW HEAD HYDRO-ELECTRIC POWER PLANTS.

CHARLES H. MITCHELL, C.E.

M. Can. Soc. C.E., M. Am. Soc. C.E., A. M. Inst. C. E., A. Am. Inst. E. E.

In the following it is the writer's desire to describe, in a very short manner, the salient features of three typical European Hydro-electric power developments, operating under low heads. For this purpose a plant is selected in each of the three representative countries, France, Italy and Switzerland.

It is probably not necessary to offer any introductory remarks regarding such engineering works, as it is well known that, in many features connected with Hydro-electric power development, European engineers lead, both in design and construction. Especially in the mechanical and hydraulic branches was this subject reduced to a science in the region of the Alps long before an equal progress was made in America. This was due to the necessities of those countries poor in coal or other fuel and rich in water powers.

Of late years, engineers on this side of the Atlantic have learned to regard European practice in this branch as the leader, so to speak, much in the same manner as the fashions in London and Paris are watched by the sartorial designers.

The following descriptions were included in an illustrated address on this subject given by the writer before the Engineering Society in February, 1907.* The illustrations shown were obtained by personal visits to these plants during the year 1906.

* These plants, along with numerous others in Central Europe, are described more at length by the writer in a series of articles in the "Canadian Engineer," which appeared during the year 1906.

LYONS INSTALLATION ON THE RIVER RHONE.

The city of Lyons with its population of half a million, is second in size, but first in industrial importance, among the provincial cities of France. This distinction is largely due to its geographic situation, since it is practically in the centre of the country, and is located at the confluence of two navigable rivers, the Rhone and the Soane; hence, secures for it a large provincial trade, and makes it an ideal distributing centre. The surrounding cities and towns contribute their share toward this activity; notably St. Etienne, with its steel works—the largest in France.

Lyons, as a user of power for manufacturing purposes, offered an attractive field for enterprise. The diverse character and limited extent of its respective manufactures calls for relatively small quantities of power, requiring a varied distribution and numerous units. The main demands for mixed power come from its silk, fancy goods, leather, wine, brewing and light metal establishments.

The Société des Forces Motrices du Rhone first undertook in 1894 the construction of a hydro-electric plant for the purpose of transmitting power to Lyons, a few miles distant, and thus became one of the pioneer European hydro-electric power producers. The site chosen for development was on the Rhone, a few miles above Lyons, and was such that high tension transmission was unnecessary. The result now is, that as in similar instances in America, a large industrial suburb, Ville-urbanne, has sprung up near the generating station, notable for its lack of chimneys and its uniformly neat appearance.

For a distance of about ten miles above the generating station, the Rhone flows through a very irregular bed, consisting of a network of rapids and small swift streams, among gravel islands, in a broad valley, having a total fall of about 35 feet. The main channel is canalized by the Government for shallow draft. The general scheme of the power development comprises a head canal from the Rhone above the rapids to a power house site, thence a tail race canal

to an outlet in the Rhone below the rapids, a total distance of about 1.1 miles, the whole known locally as the "Canal de Jonage." This arrangement affords a working hydraulic head of about 38 feet. The amount of water available is limited by the natural conditions and the requirements of the Government to from 3,000 cubic ft. per second at low water, to 4,800 at high water.

The generating station has frequently been noticed in the technical journals during the past few years; it is not the intention in this article, therefore, to enter into elaborate details, but simply to set forth the engineering features of this notable installation. The building itself is about 475 feet long, and is built largely of concrete, trimmed with stone and tiles. The units are directly connected; of the vertical shaft type, 16 in number, each of about 1,250 net h.p., under normal conditions of the river; there are also 3 exciter units. Water is led to the turbines from separate bays on the upstream side of the station, each having its own screens and sluice gate. The latter is unique, as being in the nature of a cylindrical drum, 10 ft. in diameter, closing the top of a vertical inlet pipe. It is raised and lowered by a chain hoist worked from within the station shown on the right hand side of the interior view of same.

The units are arranged in line at about 27 ft. centres. The eight central units, four on each side of the central bay—which contains the exciter units and switchboards—are operated by Jonval turbines made by Escher Wyss & Company, of Zurich, the installation of which was completed about 1897. These are of a special type, having a three stage runner with downward discharge into a draft tube, and water fed to it through three separate and parallel distributors or guides at about 45 degrees; all fitted with cylinder gates. The thrust is provided for by a large disc or piston about 6 ft. diameter, attached to the shaft within, and at the top of the case. The closed chamber on the upper side of the piston is connected to the tail race. Regulation is secured by a special governor, consisting of a rotating disc and servo-motor actuating valves in conjunction with a high pressure oil pump, by which the

gates of the turbine are operated. This turbine gives an efficiency of about 76 per cent. at full load, and the governor is said to regulate within a speed variation of 4 per cent. on a change of half load. The other eight main units, four at each end, were installed in 1902, also by Escher Wyss & Co., and are of the Francis type, having a double runner with central outward discharge, and are said to give an efficiency of about 83 per cent. It is to be noted that the latter type discharges water in the tail race with less air and commotion than does the Jonval.

FIG. 1.—LYONS—GENERATING STATION ON THE RHONE.

The electrical apparatus is very simple for a station of such magnitude. The generators are wound for three phase, 50 cycles, and 3,500 volts, and revolve at 120 R.P.M. The exciters (3 separate turbine units) provide 170 K.W. each, and revolve at 250 R.P.M. All generators are run in parallel through a simple switchboard directly to the transmission and distribution lines without transformers. The electrical apparatus was built and installed by Brown Boveri & Company, of Baden, Switzerland.

While Lyons is in Southern Europe, freezing weather is frequently experienced. In the winter of 1904-05 the thermometer

went at times as low as 5 degrees Fahr. above zero; on which occasions the station experienced trouble from frazil ice. This had the serious result of occasioning several days' shut down. It is a question whether this ice is formed in the upper river, in the foothills of the Alps, or immediately at the station; the company's engineer inclines to the latter opinion and has tried many artifices to obviate the trouble, but without success. At the time of the writer's visit, January 24th, 1906, the thermometer was down to about 15 degrees Fahr., and in anticipation of trouble, two 25 H.P. steam

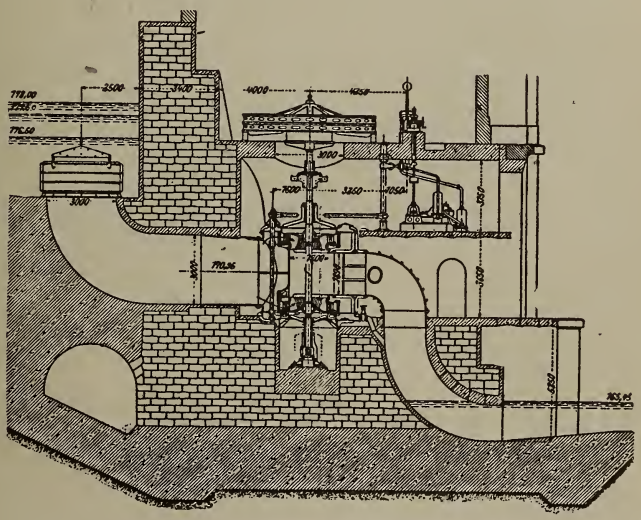


FIG. 2.—LYONS—SECTION THROUGH 1,500 H.P. FRANCIS TURBINE UNIT.

boilers on scows were supplying live steam at about 8 lbs. pressure to the covered forebays at the screens and sluice gates. To a Canadian in Southern France, in the heart of the silk country, this presented an interesting spectacle.

The power now in use amounts to about 14,000 H.P. at normal conditions. Of this, about 1,500 H.P. is traction load, 3,000 H.P. lighting load and the remainder mixed motor load. The tariff charged may prove interesting at this juncture for comparison with condi-

tions in Ontario in view of the work of the Power Commission. Good quality steam coal at Lyons is about $4.25 per ton. The prices for motor power are as follows:—Up to 100 H.P. at 11½ cents per kilowatt hour; for over 100 H.P. at $34.00 per H.P. per year on a 12-hour basis, and $45.00 on a 24-hour basis. There is a sliding discount on the above prices as follows:—On a bill of $20.00 per month, 1 per cent.; on $50.00 per month, 2½ per cent.; on $100 per month, 5 per cent.; on $200 per month, 7½ per cent.; and on $300 per month, 10 per cent. For lighting, which the power company itself operates directly, the charges are as follows:—On meter system 13 cents per kilowatt hour for stores, hotels, cafes, etc.; 10 cents per kilowatt hour for houses. If on a flat basis the lighting rate is as follows:—For a 16 C.P. lamp, burning 750 hours, per year, $4.20; for 10 C.P., $3.75; for supplementary hours, add 6-10 cent for 16 C.P. and 4-10 cent for 10 C.P. for each hour. In the flat rate the bill is determined by a time meter.

TREZZO INSTALLATION NEAR MILAN.

That Milan is one of the most prosperous and enterprising of European cities is well known. It is the centre of the great plain of Lombardy, which for centuries has been famous for its wealth in agricultural products and dependent industries. The city has always been the commercial metropolis of Northern Italy, and is now the emporium of all Italy, just as Genoa is the national seaport.

To describe the industries of Milan would require a lengthy enumeration of nearly all branches of commerce and manufacture; and the long list would, without a doubt, represent a greater diversity of interests than any American city of like size, and even larger population. The proximity of Milan to the Alps on the north and availability of economical electric power from hydraulic plants situated within transmission distance of the city has had the natural result of stimulating industry and establishing numerous factories.

The first application of electrically transmitted power was, of course, to lighting and traction, and for this purpose the pioneer

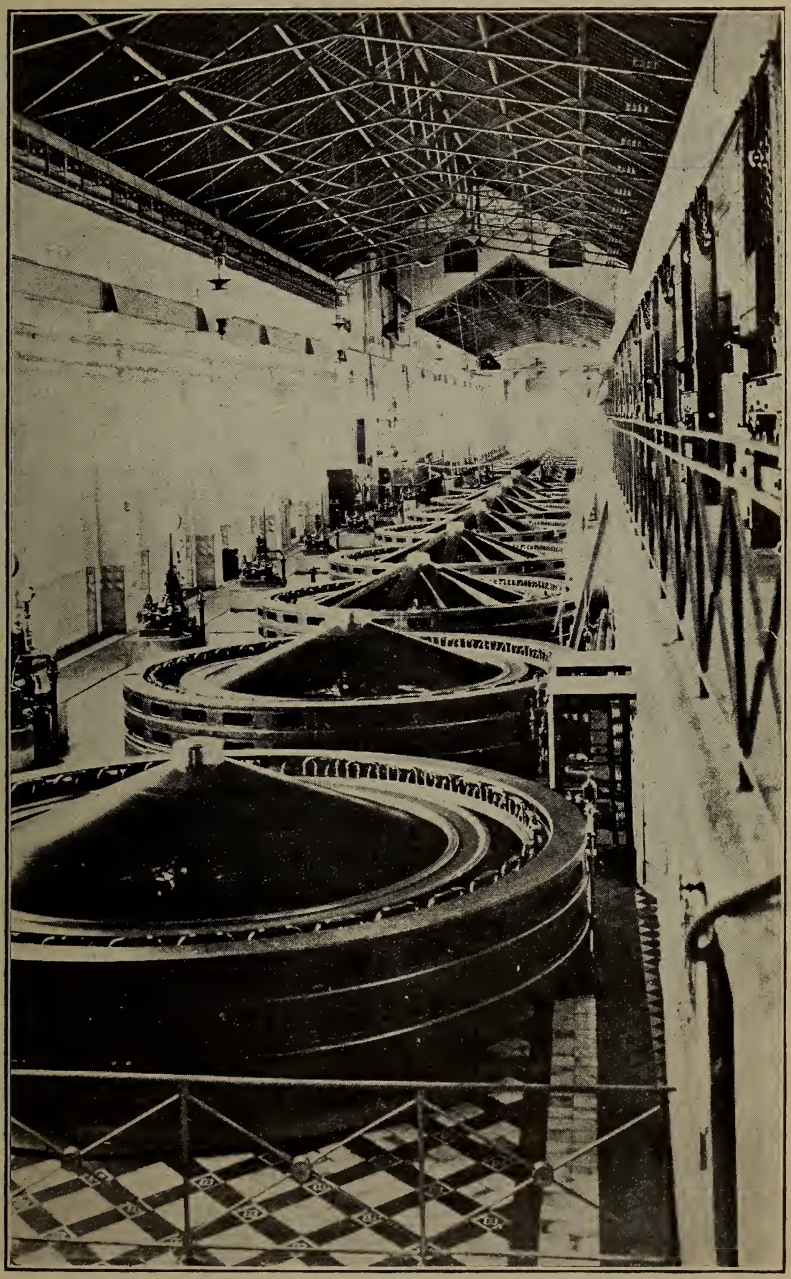


FIG. 3.—LYONS—INTERIOR OF GENERATING STATION ON THE RHONE.

company, "Societa Generale Italiana Edison di Elettricita," constructed and commenced operating a hydraulic plant at Paderno, on the Adda River, twenty-five miles north-east of the city. This was in 1898, but the same company had already a steam plant in Milan dating from 1883, with railway and lighting franchises. After the installation of the hydraulic plant, motor power for manufacturing purposes came gradually into great demand, with the result that this company not only extended its original hydraulic and auxiliary steam plants, but, with partially allied companies, has recently installed several other hydro-electric generating stations, with which the Paderno and steam stations run at times in parallel. These new stations are Zogno, 40 miles distant north-east, which commenced operation about January 1, 1905; Vigevano, 20 miles south-west, commenced operation January 15th, 1906, and Trezzo, 20 miles east, which commenced in the summer of 1906.

The Trezzo plant is selected in this article because of its very recent construction, and because of the new features introduced. The Adda River at this point (5 miles below the great Paderno station), makes a horseshoe bend around a rocky hill, and at the same time has a rapid fall. The power project consisted of damming the river at the crown of the bend, and placing a power house alongside the rock cliff, discharging the water from the tail races through tunnels, under the hill, to the river below. The low head thus obtained only 24 ft., required vertical shaft type of units, with low speeds and a corresponding large volume of water, with many units.

The construction of the dam was a very delicate operation, owing to the rise, and peculiar violence of the river after rains in the mountains, 30 miles distant. The foundations of the whole structure are of concrete, laid on the rock river bed, and, in the main portion, consist of large terraced courses of monolithic concrete, over which the water can discharge in high seasons. The upper part of this work consists of an adjustable crest formed by structural steel bents, provided with removable wooden sheeting and planking capable of raising the water to an elevation about 10 ft. higher than

the permanent concrete crest, thus forming a huge flash board system.

Against the high cliff of the river, in the horseshoe, the power house was constructed, having its face parallel to the river flow opposite, yet almost square against the current on the approach to the curve; this arrangement provides ample water with minimum deflection, and at the same time produces a sweeping current to carry past debris, etc. The station shown in Fig. 4 is situated about 300 yards up stream from the sluice gates, and is a large and very handsome structure built entirely of stone. The stones are left

FIG. 4.—TREZZO—EXTERIOR OF GENERATING STATION.

rock face, but are hewn roughly to courses, and are obtained from the cliff alongside, which is formed of a peculiar cemented gravel, resembling a thoroughly mixed hard gravel concrete. The stones after slight dressing give a very pleasing effect, which many architects would strive hard to obtain in concrete by artificial means.

It will be seen in the illustration that there are ten main water entrances, each 22 ft. wide, and two exciter inlets. These represent as many units, and the water in each, after passing screens and gates, enters a wheel pit with its vertical turbine, thence into the tail pit

and common bay, about 300 x 60 ft., in the rear of the station. From this point the water is conveyed by means of two tunnels beneath the cliff to the lower river. For a distance of 150 ft. above the station and in continuation of the face of the water inlets, a series of 10 overflow weirs is arranged to take care of slight inequalities in the river level.

The vertical turbines are Francis type, each of 1,500 H.P. capacity at 105 R.P.M.; the first six and the two exciter units are by Riva Monneret & Company, and the seventh is by Escher, Wyss & Company, of Zurich. Considerable use has been made of re-inforcing steel in the concrete foundations and settings of these machines. The governors are connected by two stems to the gates. In general arrangement (see Fig. 6), the power units are similar to those at Lyons already described. The generators are of 3-phase revolving field type, two at 50 cycles, and the remainder at 42 cycles, and are built by Gadda & Company, Milan.

In the arrangement of switches, transformers, arresters, instrument boards, control, etc., this station is, if possible, more complete and roomy than that at Vigevano, and the whole large wing at the end of the station is occupied by this apparatus. The distant control apparatus is, in itself, a very perfect arrangement, permitting complete operation from table switchboard to isolated apparatus in different compartments of switch and transformer rooms.

Four transmission circuits, three to Milan and one to Bergamo, are now in operation at 13,000 volts, carried on structural steel towers known as the "Elastic" type. The function of these towers is that while rigid at right angles they will oscillate slightly in the direction of the line, creeping of the cables being prevented by guying at intervals. These towers are 40 ft. high above ground, built with two legs (channel section) 7 ft. apart, and each leg set in concrete 5 ft. deep; the top of each leg member carries two circuits. Insulators on these lines are of the Paderno type, but are being partially replaced with a new design recently patented by Signor Semenza, consulting engineer of the company. This is a radical depar-

ture, but most simple, with qualities of insulation which are obvious. The design, which can be better illustrated (Fig. 5) than described, consists of the lower portion of a simple Paderno insulator, provided with a threaded top and side groove in which the wire passes: over the top is screwed an "umbrella" made of terra cotta about 12 in. in diameter, having a small watershed arranged on each side above the wire. It is interesting to know that in the break-

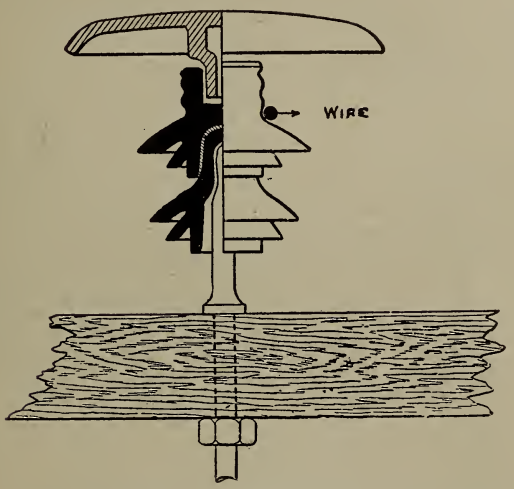


FIG. 5.—SEMENZA UMBRELLA TYPE OF INSULATOR.

down tests on an insulator designed for 30,000 volts, the ratio between wet and dry conditions is nearly unity, viz.: 122,000 volts for dry and 110,000 volts for wet. A feature of this new type is its small cost, the expensive, large upper part of the usual porcelain insulator being replaced by a simple, easily formed piece of terra cotta or other cheap material. As jokingly pointed out by Sig. Semenza, a new umbrella is, in this case, cheaper than an extra petticoat.

THE BEZNAU PLANT IN SWITZERLAND.

One of the most interesting low-head plants in Switzerland today is that situated on the Aare River, near Baden, known as the

FIG. 6.—TREZZO—INTERIOR OF STATION.

Beznau Station. In it are constituted all the most recent improvements in the application of the water to the wheels, and in the wheels themselves are embodied the rsults of the experience of the past ten years, with plants operating low-heads with large variations. This plant was completed and put into operation in 1904, and was quickly loaded up with consumers in the surrounding country.

The water is obtained by cutting across a bend in the river with a canal about three-quarters of a mile long, and the generating station is placed across the lower end. A removable series of screens is provided, and also commodious spillways, although all ice and debris is deflected at the headworks. The generating station below the floor line is built of concrete, the superstructure being of stone.

The available fall varies between 10 and 15 feet, and, owing to this variation, the vertical turbine units consist of three runners 7 ft. 6 in. diameter. One pair of runners is at the bottom, right and left, and the third above, discharging downwards into the draft chamber of the upper runner of the pair, see Fig. 8. At a medium head of 13 ft. 1,000 H.P. is obtained on each unit at 67 R.P.M., using 890 sec. ft. of water. The whole unit is supported by hydraulic pressure beneath a disc, so as to reduce the weight on the step bearing, and the small inequalities of this are further balanced by oil pressure from special pumps.

Regulation is secured by an oil pressure governor geared to the main shaft, standing on the station floor, which is attached to the gate shaft. Links from the latter are connected up to the gate rings surrounding the distributor of each runner: to the gate rings are linked the swivel gates, which, by rotating the ring, open and close on the fixed vanes of the distributor, thus admitting water as required to the runners. The turbines are built by Theodor Bell & Co., of Kriens, near Lucerne.

The power secured in these units varies between 7,000 and 11,000 H.P. for the whole installation of nine units.

The generators are of the umbrella revolving field type, 800 K. W. each, three-phase, wound to 8,000 volts at 50 cycles, and were

FIG. 7.—BEZNAU—INTERIOR OF GENERATING STATION.

built by Brown, Boveri & Co., of Baden. Local distribution is at the generating voltage, while long distance is at 25,000 volts up to 20 miles. The latter voltage was the highest in transmission operation in Switzerland at the end of 1905. The total length of transmission lines of this plant in 1905 was 70 miles, the number of localities served was 61, the population 250,000, the number of transformers 60, and stations 31, while the average power of motors served was 100 K. W., in which respect this plant stands third in the country.

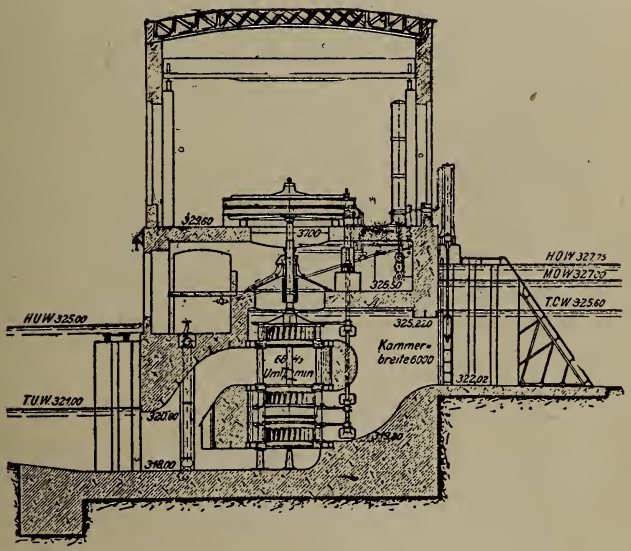


FIG. 8.—BEZNAU—SECTION THROUGH UNIT.

Prices of power are generally as follows: For lighting 16 C.P. lamps, $4 each per year, continuous service. For motors on 10-hour basis flat rate, 1 H.P. at $43; 10 H. P. at $39; 50 H.P. at $34, and 100 H.P. at $32. For 24-hour basis, 1 H.P. at $56; 10 H.P. at $49; 50 H.P. at $44, and 100 H.P. at $41.

MODERN STEEL BUILDINGS.

JOHN M. EWEN, M. AM. SOC. C.E.

I shall speak to you this afternoon about modern steel buildings and also about the modern methods of business organization which are necessary to the rapid and efficient construction of such buildings.

The first big building in which the idea of a steel frame was used to any extent was the Home Insurance Building in Chicago. This building was erected in 1883. Only 24 years have passed since that time. You can see therefore that the whole revolution in modern building construction has been condensed into a space of less than a quarter of a century.

The principle first embodied in that building has completely changed the character of big building construction. But there has been a change not only in the buildings themselves, but in the methods of organizing the architects, the engineers, the contractors, and the artisans, who construct the buildings. Fifteen years ago the erection of an eight or ten-storey building was considered a good year's work. To-day a building twenty-five or thirty storeys high can be erected within that same length of time. This change is due to improvements in methods of work. The modern construction engineer, engaged in the erection of big buildings, has a business organization which differs from the business organizations of 25 years ago, almost as much as the steel building itself differs from its solid-masonry predecessors.

As an example of the rapidity with which a modern engineering force can work, we may take the Sears-Roebuck plant on the west

side of Chicago. This plant consists of four large buildings. The largest in the group is ten storeys high, four hundred feet wide and sixteen hundred feet long. The total cost of the plant, including all buildings, was more than four million dollars. Yet the whole job was done in eight months. In other words, building construction has not only been changed but accelerated. It is not only different in materials but different in methods. It has not only more steel but more speed.

And, by the way, the speed is just as important as the steel. When an old building is torn down in the heart of a great city, the owner loses his rents from the time when the old tenants are turned out to the time when the elevators begin to carry the new tenants to their new offices. Can the engineer constructor have that new building ready in ten months, or will it take him eleven? The difference of one month is important. There are office buildings which have a monthly rental roll of fifty thousand dollars. That sum represents to the owner the difference between an engineer constructor who can put up his building in ten months and the engineer constructor who cannot do it under eleven. It is therefore absolutely necessary that the modern engineering force should be able to do its work, not only with the utmost care, but with the utmost rapidity. This means that the best type of engineer constructor, in order to be able to handle big building operations, must have in his own office, or else closely associated with him, all the different kinds of talent which go into the construction of the modern skyscraper. In other words, the modern engineer constructor is not an individual. He is an organization.

You will be able to see what I mean if I just name the different kinds of trained men who ought to be included in an engineering force competent to perform a modern building operation with the smallest possible loss of time. An architect; a civil engineer; an electrical engineer; a mechanical engineer; a structural engineer; a sanitary engineer; a fire protection engineer; a purchasing agent; a construction superintendent; an operating engineer; an accountant. For the best work, it is no longer advisable to have all these men

in separate offices of their own and to call them in from time to time in an advisory capacity to superintend their particular part of the work. It is better to bring them into what is, in effect, a single organization. They must work like the players in a football game, not as individuals but as a team. And they must have a captain whom they all trust and whom they all obey. He is responsible for every play in the whole game. He directs every movement. But he must have men under him who know their own specialties just as the left tackle in a football team knows how to be a left tackle, or the half-back knows how to be a half-back. The captain can then send that team down the field and have it under complete control and know what every man is doing every second. The difference between the old-style football of fifty years ago, when the players roamed all over the field very much at their own sweet will, and the modern organized football, in which the whole team is under perfect control, and moves like one man, is the difference between the scattered individuals who used to collaborate in the construction of a building fifty years ago, and the modern compact engineering force which brings all those individuals together in one team and which can calculate, almost to a day, the exact time which it will consume in getting a certain piece of work done.

Let us begin now at the beginning and see what happens from the time when a man decides that he wants a new building to the time when that building is handed over to him, ready to be used. We will suppose that our man comes to the office of an engineer constructor of the kind we have been talking about. He explains that he has an old building which will have to be torn down and that he wants to replace it with a modern office building on which he is willing to spend a certain amount of money. He naturally wants as much done with that money as possible. The engineer constructor now proceeds to make a prophecy of that new building, complete in every detail. There are men in the office who can estimate the cost of every particular kind of thing that will be needed. Each man can make a pretty fairly accurate forecast of the expense that will be connected with that feature of the building in which he is par-

ticularly interested. The advantage of such a careful estimate of prospective cost is manifest. The owner of the building then knows exactly what kind of building he can afford and just about how much money he will have to spend. This is an advantage which in former days it was sometimes very difficult to secure.

There have been times when an architect would draw plans that were attractive to the owner and that promised a building of a kind that he would enjoy possessing. These plans having been all made and the dimensions and decorations of the building having been decided upon, the different contracts for steel, brick, granite, etc., would be awarded, one after the other. Everything would go on pretty well till one day the architect would come to the owner and say: "Well, I am sorry, but that building will cost three hundred thousand dollars more than we thought it would." In fact, there is one architect who always introduces some humor into the situation and says: "Well, you'd better go out and take half a million dollars more away from somebody. We'll need it before we get through." These things are often quite annoying to the owner. They are avoided when architects and engineers work out the plans together and when the architects can compare their ideas of what would be desirable with the ideas of the engineers as to what is financially possible.

The exactness with which a financial estimate can be made was seen in the case of the new County Building for the City of Chicago. When the plans for that building were being drawn up it was known that there was a certain appropriation for it, and every effort was made to draw the plans in such a way as to make allowance for every possible detail and still keep within the appropriation. Finally after the estimate had been made, and after the specifications for the steel contract, the granite contract and all the other contracts had been printed, showing just what was wanted, the contractors were all asked to come in and bid on the work. When all the bids were in, and when all the contracts had been awarded, it was found that the actual contract cost was only fifty thousand dollars away from the estimate of five million dollars that had been made before

any of the contractors had named their price. When building can be done in this way, it saves the nerves of the owner. If the estimate is too high, he can cut his plans and try to satisfy himself with a more modest building. If the estimate is satisfactory he can order the engineer constructor to go ahead.

The engineer constructor must now plan his campaign like a general. He must not allow a moment to be lost. And in order to avoid the loss of a moment he must lay out a complete time schedule for his building to follow. The civilian is likely to imagine that the general of an army simply starts out in the direction of the enemy and wanders along till he finds him. In the same way the man who is not familiar with engineering practice is likely to think that the engineer simply starts building and keeps on building till some day he gets through. As a matter of fact the first thing that an engineer does when he begins a building is to calculate practically the exact day at which that building will reach each successive stage in its construction. In other words, he writes a diary for that building, but he writes it beforehand instead of afterwards. This table of dates shows the exact stage at which the building is scheduled to arrive on the days mentioned. It gives everybody connected with the construction of the building his cue for coming on and going off. It is the running-time for the construction engineer just as the time-table of a railway is the running-time for the locomotive engineer.

As we go on now with our building we will suppose that the owner wants a building with a steel frame. It is a mistake, however, to suppose that a steel frame is absolutely essential to the construction of a high building. There is one reason, among others, why a solid-masonry building would be unsatisfactory to the modern owner. The walls of such a building have to be extremely thick. They must be immensely broad and strong in order to support the weight of the structure. The consequence is that a great deal of space that might be used for offices has to be used for walls. If such a building had a steel frame, the walls would be so much thinner that the floor-space, capable of being devoted to offices, would be increased by twenty-five per cent. Obviously it is to the advantage

of the owner to build with steel. The old County Building, Chicago, furnished us with an illustration. The walls of this building were twenty feet thick at the first floor. The walls of the new building, which is steel construction, at the first floor, are only three feet thick. The saving in floor space is obvious.

There is also another reason for preferring steel-frame buildings of the most modern construction to buildings of the old type. This second reason is their superior safety.

Masonry by itself, or slightly and imperfectly supported, cannot sustain a severe shock or jar of the kind given by an earthquake. This was demonstrated in the San Francisco disaster, where buildings of the old type tumbled down, while the steel frames of the modern buildings were practically intact after the earthquake and after the fire. The reason is to be found in the method of construction. The steel columns and beams were so firmly fastened together with rivets and so strongly braced that the whole frame-work was practically as stiff and rigid as a steel cage. The masonry walls were carried on the outside steel beams and were tied to those beams with strong iron anchors at every floor. Finally another precaution was added. Under the window sills of each storey a flat band of iron, about five inches wide, and a quarter of an inch thick, was laid in the masonry and carried all the way around the whole building. This band of iron is riveted to the columns as it passes them and acts as a horizontal support for the masonry. The whole building could actually be tipped several feet out of a vertical line without endangering its integrity.

For reasons of safety, therefore, as well as the desire to get more floor-pace, the owner of the prospective office building is likely to want a steel frame.

The plans made by the engineering force for the new building will now show exactly where every piece of material is to be put. When the building is completed the thing that seems remarkable is its size. When it is being built the thing that seems remarkable is

its infinite number of small details. All these details are represented in the plans. These plans, specifications, blue prints and documents of all sorts multiply at an astonishing rate. If they were all brought together in the case of a building like the Cook County Building in Chicago, and put on a scale and weighed, they would tip the beam at something like thirty tons. At this stage it is not the big work of engineering practice, but the small work, that attracts the eye. On the tables in the architects' and engineers' offices, where the plans are kept, they give a complete picture of the building which has not yet been begun. The smallest piece of steel that goes into a column up on the fifteenth floor of the building is already in its place, its exact place on the plans. The building exists completely in imagination before a single stone has been placed in the foundations.

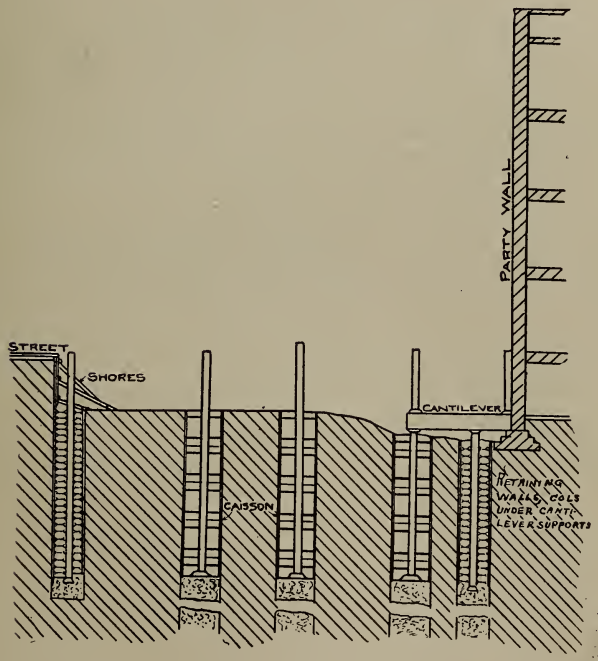
The engineer constructor, if he is in complete charge of the building, will now proceed to let the contract for tearing down the old building. The contractor who does the job of taking it away will make good use of all the usable materials it contains. He will have a big yard or warehouse in which the steel, the iron, the stone, the bricks and the other materials will be sorted out and heaped up and sold to people who can use them. In some cases the stone from the old building is crushed on the spot and mixed with sand and cement to make concrete to be used in the new building.

While the old building is being battered down and carted away, other contracts are being let. It was formerly customary to follow up the demolition of the old building immediately with the excavation of the space for the foundations and basements of the new building. It is now feasible, however, to do the foundation work before doing the excavating. This seems like a contradiction in ideas. But the process is comparatively simple. And it saves a great deal of trouble.

If you follow the old method and dig the big hole in the ground before you lay your foundations you have to support the sides of this hole with long, strong timbers, and you are constantly worried by

the fear that some of these timbers may slip and break and that the building next door or the pavement of the street may feel the jar and may be more or less seriously damaged.

Suppose, for instance, that the building has been torn down, and that you have proceeded to make a large excavation. You can readily see that it is necessary to take great precautions in order to protect surrounding property from injury. Instead of taking this



OLD BUILDING DOWN ; WALLS IN ; CAISSONS COMPLETED AND COLUMNS SET.

risk, you may, if you please, allow almost all the dirt to remain in place and get your foundations all in before you dislodge it.

You begin by digging a trench along the sides of your lot. The sides of this trench you support with horizontal planks which are braced apart by screw braces. Finally, when the trench has reached the desired depth of your lowest basement, you put in a concrete base at the bottom of it and instal vertical steel beams all the way

up the middle of it from bottom to top and brace these beams with jack-screws, set between them and the planks which still form the sides of the trench. The pressure from the street and from the earth and the buildings surrounding your lot is now transmitted across the trench through the planks and the jack-screws, and the steel beams, and is now successfully resisted by the big core of earth which you have left still occupying the whole centre of your lot.

You are now ready to dig the wells for your caisson foundations. At various spots on your lot, that is, wherever you intend to have a steel column for the support of your building, you begin to make a round hole. The rest of the earth on the lot remains unexcavated, just as it was. All the excavating you now do is simply for holes which will afterwards be filled with concrete and used to support your steel columns.

The depth to which you dig these holes will depend upon the size of the building and the character of the soil. In Chicago you may choose between two different levels. One is hard pan. The other is bed rock. The first is found about sixty feet below the surface in the down-town district. The second is not reached till you have gone down one hundred and ten feet. In the case of a large building it is usually advisable to go all the way down to the second level.

As these wells are dug they are lined with heavy strips of wood, called lagging, and they are further protected by the insertion of metal rings which keep everything steady and transmit all pressure from every side. The digging is usually done by hand, with shovel and pick, and is good, hard work, especially when the laborers get down toward bed rock. Recently, in a caisson well six feet in diameter, two men worked for eight hours and made only eight inches of progress.

When the wells have finally reached the requisite depth, they are filled with concrete to the level at which the bases of the columns are to be set. The bottom of the well has previously been somewhat enlarged, or "belled out," so as to transmit the weight of its load

over a large area. The rest of the well is of the same diameter throughout.

These columns of concrete are commonly called caissons, though they do not, strictly speaking, deserve that name. The word caisson, in engineering practice, really refers to a foundation which is made under water by men who are working in a chamber filled with compressed air. Caisson disease is the disease which men get through breathing the compressed air in a chamber of that kind. Our caisson wells in Chicago are not built under compressed air at all. They are simply dug with a shovel and pick, just in the same way in which any ordinary excavation is made.

General William Sooy Smith, a famous American engineer, recommended the use of what we now call caisson foundations at the time when the Masonic Temple was built twenty years ago. At that time the idea was not thought feasible. Later, however, it was tried in the Stock Exchange Building of Chicago, and it soon began to win its way into favor.

Of course, the other kind of foundation is still used. In many cases long piles are driven down into the ground and the building rests on them. Care must be taken, however, to see that the heads of the piles are driven down below the water level. Otherwise, they will rot.

In other cases, the foundations consist of what might be called rafts of steel beams, placed closely together, and set in concrete. These raft foundations, or floating foundations, support the columns which in turn support the floors.

One disadvantage about pile foundations and about raft foundations is that they settle when the weight of the building is imposed upon them. It is therefore customary in such cases to build the first floor of the building several inches higher than it ought to be, and then wait for the whole structure to settle down to its proper level. In some places in the down-town district of Chicago, you will notice that the sidewalk slopes from the building to the street.

This means that the building did not settle as much as its builders thought it would. In other cases the sidewalk slopes the other way. That means that the building was made heavier than was expected and that it settled too much, so that the slope of the sidewalk is toward the building from the street.

Another disadvantage about raft foundations is that they take up a great deal of space. Sometimes they even extend over into the next lot under the adjoining building.

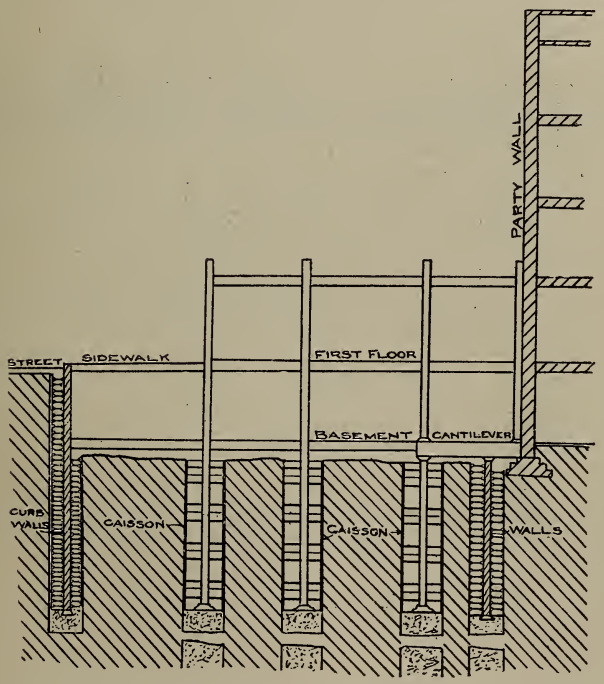
A case of this kind was once carried to the Supreme Court. It was a dispute between Mr. Field and Mr. Leiter. Mr. Field won. The Court decided that he had the right to extend his foundations into Mr. Leiter's property. I was connected with the controversy in the interests of Mr. Field, and it became my duty to go to Mr. Leiter with the necessary drawings and show him exactly what we intended to do. There was to be a floating foundation 26 feet wide, thrusting itself under the party wall and resting half on Mr. Field's property and half on Mr. Leiter's.

Mr. Leiter studied the drawings carefully for a long time and then said, "Well, what shall I do if my neighbor on the other side should wish to perform the same kind of building operations as Mr. Field? He would want a similar foundation of the same width, 26 feet, and would naturally want thirteen feet of my land. This would make 26 feet of land that I would be obliged to furnish. Now, as I have only 25 feet, do I not run the risk of being sued for not having land enough to accommodate my neighbors?"

Let us now go back to our own building. The wrecking contractor has removed the old building. The foundation contractor has dug the caisson wells and has filled them with concrete. We now have our concrete columns on which to rest our steel columns, and we are ready to go ahead with the erection of the building.

Meanwhile the core of earth where the basements will be is still in place. We have saved a good deal of time by letting it stay there and by getting the caisson wells dug and filled first. If we

had spent our time excavating we should not be able to begin on the steel work till late in the season, and then the cold weather would come on and the men would be subjected to hardships and the work would be delayed. Now, however, we shall be able to get all the outside work done during good weather, and by the time winter comes we shall have the shell of the building completed and we shall be able to turn some steam on while the plasterers and decorators are finishing the interior.

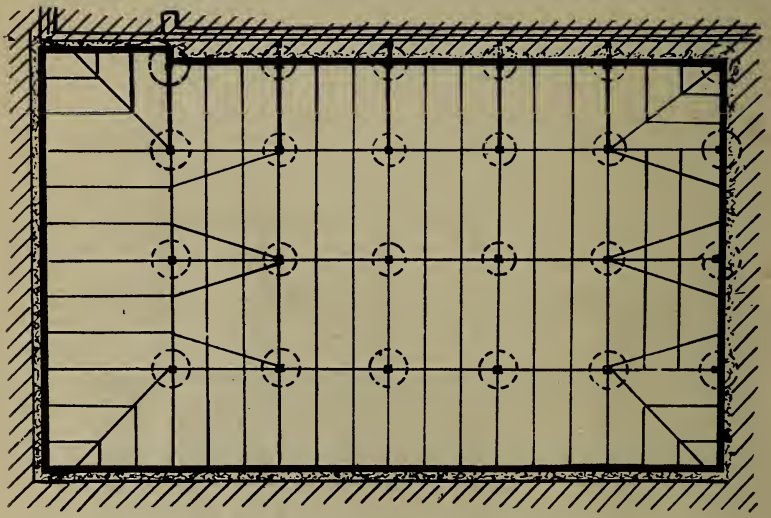


FIRST FLOOR AND BASEMENT FLOOR BEAMS IN ; EXCAVATION IN PROGRESS ; SUPERSTRUCTURE GOING UP.

Meanwhile we can do our excavating at our leisure, and we can go as far down as we please and put in as many basements as we desire.

It is coming to be customary to go forty feet downward in Chicago and to have three or four basements.

Deep basements have become very desirable in Chicago ever since the freight tunnel was built. This tunnel is forty feet below the street level. It is about seven feet in diameter and fifty miles long. It runs underneath practically all the streets of the down-town district, and it extends south to about Archer Avenue, west to about Halsted Street and north to about Chicago Avenue. It is designed to carry coal and merchandise and mail and express matter and anything else that can be transported in a bore of this diameter. To a considerable extent it is intended to relieve the congestion of teams on the streets above.



PLAN OF FLOOR BEAMS AS USED IN BASEMENTS.

In order to get down to the tunnel a building must have at least a third basement. Then it can receive its coal and get rid of its ashes, and do a lot of other work without cluttering up its sidewalks or its backdoors.

Altogether aside, however, from the advantages connected with a freight tunnel, it seems likely that the buildings of the future will have a great many basements. Land is so valuable in the heart of a great city that as we have been forced to go upward instead of spreading out, so we shall also be forced to go downward.

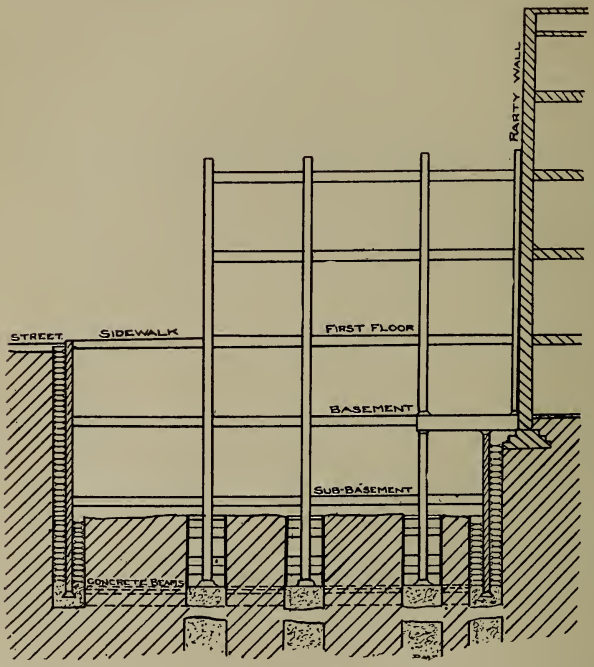
Using the methods we have already described, it would be perfectly feasible to construct a building with eight of its storeys underground. Such a building could be lighted by means of an interior court, extending all the way from the top of the building to the bottom of the lowest underground storey, if desired. From the engineering standpoint, there is practically no limit to the height or depth of a building. That is, of course, within reason. When you have caisson foundations, resting on bed rock, you have a basis on which you can construct twenty, thirty, fifty or sixty storeys without danger. The real limit is the financial willingness of the owner to pay for the expense of carrying on building operations at so great a height, and the personal willingness of the tenant to put in his time travelling from the fiftieth storey of one building to the fiftieth storey of another. The speed of the elevator service here becomes an important consideration. Such matters, however, are not directly connected with the actual feasibility of erecting high structures. Such structures can be built. And they can also be extended as far downward into the earth as is financially desirable.

Already there have been successful experiments in this direction. The Criterion Theatre in London is an underground theatre. The floor of the Criterion Restaurant forms its ceiling. The theatre is entirely underneath the restaurant, and the restaurant is at the street level. This is an extreme case. But it might frequently be desirable to build a theatre with its first balcony at the street level. One advantage of this plan would be that in case of fire the people in the second balcony would have a better chance to get out. They would be one storey nearer the ground.

Let us now return once more to our new building. While the basements are being excavated, the steel contractor is getting his columns erected and is starting the building on its upward course.

Meanwhile the other contracts have most of them been awarded. The brick, granite, the terra cotta, the ornamental iron, the elevators, the boilers, the electric wiring, the rubber mats, everything goes under contract. In quarries and in foundries and in factories the

materials that are to go into our buildings are being dug and shaped and burned and rolled and pressed and stamped and tested and prepared for shipment. In addition to the engineering plans we now have shop plans, which go to the places where the materials are being made ready. Each piece of steel or iron or granite or terra cotta arrives clearly marked or numbered so that the workmen will know just where to put it. These workmen are employed by the



SUB-BASEMENT BEAMS ALL IN ; STEEL OR CONCRETE BEAMS BETWEEN SIDE WALLS IN CELLAR.

contractors. The contractors have foremen who are in direct charge of the work. It is the business of the engineer-constructor to watch the contractors and their foremen and their workmen, and to see that they work harmoniously, and that they finish their part of the job on schedule time. The engineer-constructor tells them on what day they are each of them to begin, and on what day they are each of them to finish. He provides them with a schedule showing at just

what stage of progress they ought to arrive on certain successive days. The engineer-constructor therefore has his representatives on the site of the building every day. He is responsible to the owner for the accomplishment of the work and the owner deals with the contractors through him.

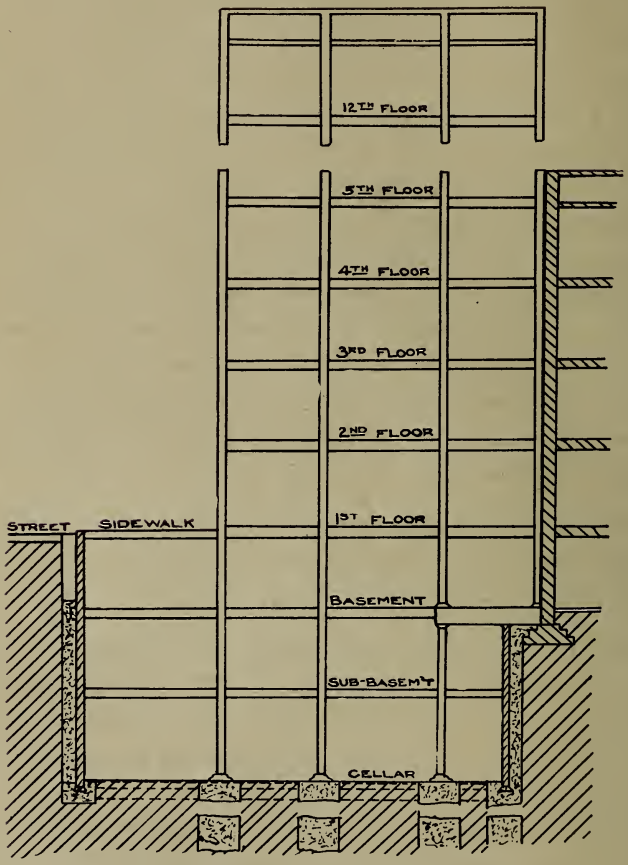
In speaking of the engineer-constructor in this way, we are assuming that both the architect of the building and the consulting engineer are in the same business organization or that they work together as a unit. If, however, the consulting engineer and the architect come from separate offices, then both of them keep representatives on the job and frequently visit it in person. Whether they are personally associated in the same firm or not, they after all represent the same idea. That is, they furnish the technical skill and knowledge through which the owner works in paying his money to the contractors. The contractors do the work of erection and are paid fixed sums for their labor and material. The engineer-constructor is usually paid a certain percentage on the total cost of the work. There are other financial methods under which buildings are constructed, but this is a quite usual one.

As the steel columns are going up it should be noticed that each one of them consists of a large number of different pieces of steel, all soundly riveted together.

Piece by piece, then, the columns rise toward the required height of the building. As they go up, the contractor erects steel girders between them at the floor levels and then erects steel beams between the girders. The floors therefore will be supported by the beams and girders; the beams and girders will be supported by the steel columns; the steel columns will be supported by the concrete caisson columns; and the concrete caisson columns will be supported by bed-rock. A building of this kind, carefully erected, is about the safest kind of building ever devised.

Right next to the steel comes the terra cotta or concrete fire-proofing. Each column in a fire-proof steel building is encased in terra cotta from top to bottom. This is called fire-proofing the steel.

Terra cotta is a clay product that has been burned with exceptional thoroughness. It has come to have a large place in building operations. And it is used not only to encase the steel frame of the building, but also to form the arches of the floors and in a more refined state to cover and ornament the street elevations of the building.



STEEL FRAME COMPLETED.

As the terra cotta, piece by piece, begins to creep over the steel, the brick contractor and the stone contractor begin to follow.

The brick and stone for the walls of the building rest usually on the outside beams and girders, called lintels, of each storey. That

is, the masonry of *each* storey is really a structure by itself. That is why it is possible to do the masonry work on an upper storey before the masonry work of a lower storey has been started. Brick, stone and terra cotta may all be used in the walls of modern steel buildings. But they are only a shell. The kernel is the steel frame.

While the steel columns are being fireproofed with terra cotta, and while the walls are being built, the floor arches begin to appear. These arches are built on the ordinary arch principle, with key-stones and subordinate pieces. They are sprung between the beams and girders at each floor level. They support the weight of the flooring itself.

This flooring, on which people will stand, may be made of wood or stone or marble or concrete, or any other suitable material. But it is not the real floor. It is just a coating. The real floor consists of the floor arches. The floor arches sustain the weight of the flooring and of the things and people on the flooring.

When the steel frame has been erected and fireproofed, when the walls have been built, when the floor arches have been sprung, it is clear that the big outlines of the building have been completed. But meanwhile everything else has begun. The staircases are going in. The elevators are being installed. The boilers are being moved into the basement. The woodwork of the doors and windows is being erected. Glass is being moved into place. All these things keep happening at the same time, and unless they are managed harmoniously the building will be delayed.

When the last tap of work has been done and when the building is ready to be handed over to the owner for occupancy, we can stand off and take a look at it. Six months, or twelve months, or eighteen months, depending upon the size of the building, have passed since the wreckers were let loose on the old structure. Since that time, the engineer in charge may have spent five million dollars on behalf of the owner. Of such a sum about $600,000 may have been spent on steel and about half a million each on brick and stone. In the new County Buildings, Chicago, there are 35,000 different pieces of steel

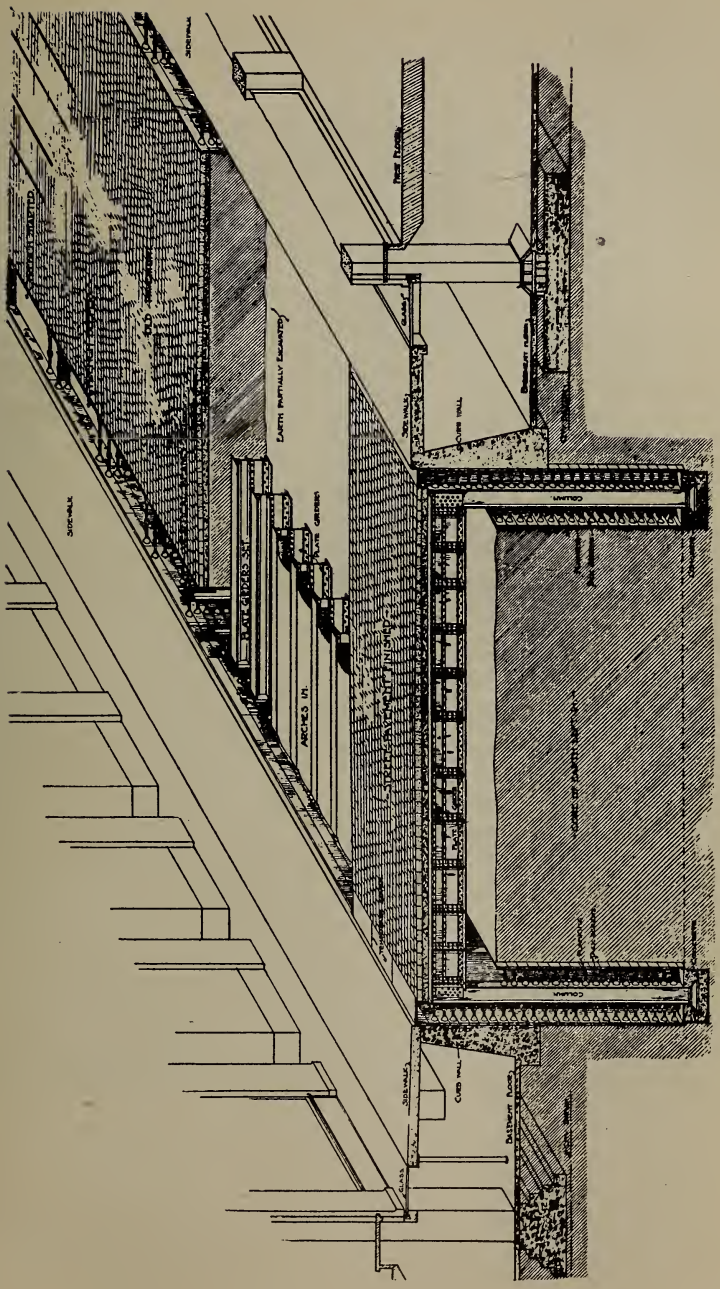
besides 500,000 rivets. The steel pieces in that building, set end to end, would reach 250 miles. If the same weight which exists in these steel pieces were put into an iron bar a quarter of an inch in diameter, it would reach all the way around the world, with a thousand miles to spare. The granite in the County Buildings weighed more than 11,000 tons. Five hundred cars were needed to haul it from the quarries. The scope of such a structure, and its wealth of detail, are overpowering.

But let us take a look at its strictly architectural features.

Most modern steel buildings are erected for purely commercial purposes. The owner has land of a certain value. He puts up a building of a certain value. And he naturally wants to get the largest possible return on his investment. The architectural features of the building are therefore the features in which he economizes, except in so far as the public comes to demand a handsome building for business purposes. In some cases a big firm will erect a handsome building simply as an advertisement. In such cases the architect is freer to devote himself to the development of a beautiful structure. But the usual rule is that the building is strictly commercial, and that the owner is satisfied with such architectural beauty as will be sufficient to attract tenants. And perhaps it is more fortunate in some respects for the architect when the owner looks at the proposition in that way. For when the architect is given a free hand his troubles begin. The modern steel building is more difficult to harmonize with the traditional rules of architecture than any other kind of building that was ever invented.

One of these traditional rules is, for instance, that the building shall look to be what it really is, that it shall not be a sham, that it shall be sincere. Now a modern steel building has a steel frame. Yet, on the outside, it looks as if it were made of stone and brick and terra cotta. This is clearly inconsistent. And it is an inconsistency that runs all the way through the building.

In many a steel building, for example, you will find beams that are carried across the ceiling in certain big rooms and that look as



SECTIONAL ELEVATION.

if they were supporting the ceiling. Yet, if you are familiar with construction, you know that they are not supporting the ceiling at all.

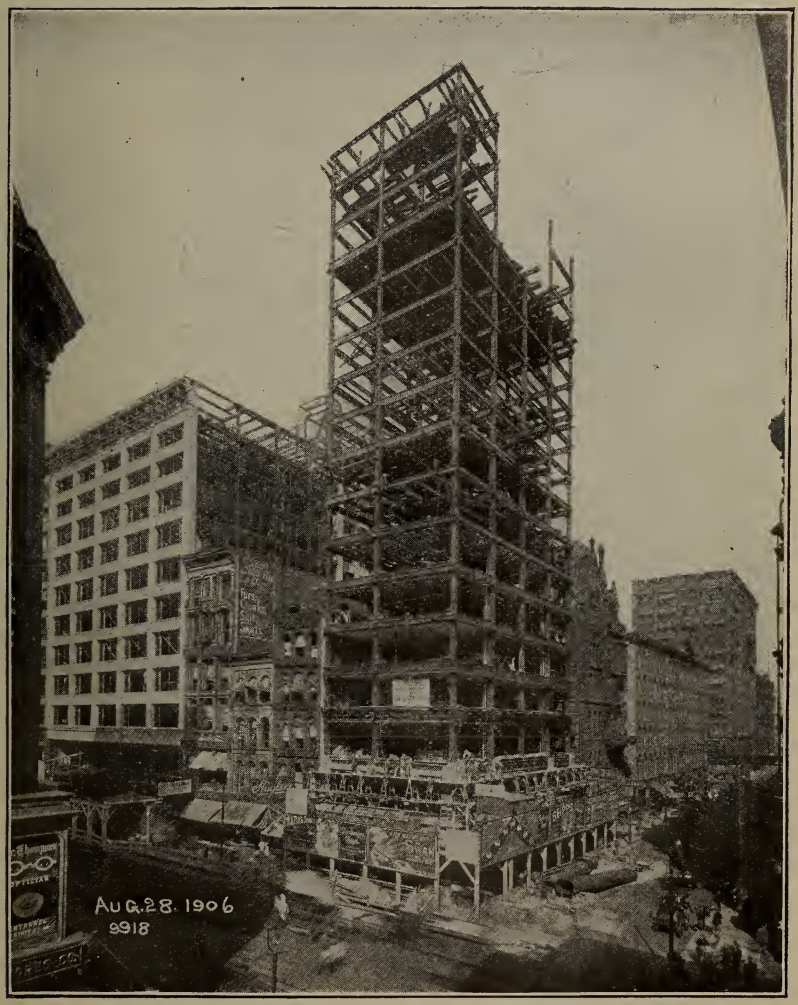
These beams are simply made out of plaster and other similar materials. They support nothing. They are themselves supported by the floor arches and the beams and girders. They are not architectural construction. They are simply architectural decoration.

These grand columns that we see so often on the exteriors of buildings might theoretically be supposed to consist of big, single pieces of stone or marble, worked into the proper shape. As a matter of fact, they are in all probability nothing of the kind.

If they resemble a great many of the columns that have been erected in modern times they are built out of a series of separate pieces about five feet in height, these pieces being placed one on top of the other. It frequently happens that the eye is even more grossly deceived. Each piece of the column (technically called a drum) may consist of several smaller pieces tied together with pieces of metal called dowels. The column may be hollow in such cases or may have concrete work and masonry inside it. It may also be anchored by other pieces of metal to a steel column. The architectural column then consists of metal, of concrete, of masonry, of hollow spaces, and of pieces of stone joined together to form drums which then, arranged in a vertical series, produce a column-like effect.

Such a column is extremely painful to some people. But this is merely incidental. The fundamental difficulty is to make a steel building look sincere, that is, to make it look like a steel building.

Now the central fact in a steel building is the steel column. Yet how can the fact of the existence of steel columns be even indicated to the occupant of the building? In the first place, it has to be concealed with terra cotta in order to render it fireproof. In the second place, it has to be still further concealed in order to make it attractive to the average eye. The steel column, by itself, is a com-



CHICAGO SKY-SCRAPER, SHOWING STEEL ERECTED AWAY IN ADVANCE OF MASONRY.

paratively narrow and superlatively angular and ugly thing. People demand that it be padded out and made to look symmetrical before it is allowed to appear in the walls of the finished rooms. If the steel column were exhibited to the tenant in its original shape it would look sincere, but its sincerity, like that of many human beings, would not bring it many friends.

The difficulty we have with the column is the difficulty that exists for the whole building. The frame of the building must be of steel. Yet it is very puzzling to discover any way of finishing the rest of the building with any reference to that fact. As things stand to-day, the modern office building continues to look as if it depended on masonry while in reality it depends on metal.

THE WORKS OF THE VANCOUVER POWER COMPANY (LTD.).

E. B. Hermon, '86.

The birth of Vancouver, British Columbia, may be said to date from the building of the Canadian Pacific Railway, and its extremely rapid growth to a city with a population of over 50,000 marks an era in the history of the marvellous development of the Pacific Coast. Situated on the eastern shore of the island-protected waterways characteristic of the North Pacific, surrounded by mountain ranges towering four to seven thousand feet above sea level, possessing a magnificent harbour, and being the terminus of trans-continental railways, Vancouver was destined to become a place of magnitude and importance.

In keeping pace with the rapidly increasing demand for power, light and street car service, the electric interests in Vancouver at length found a limitation to the numerous additions to their original steam plant. In the course of a few years one unit after another had been installed, until many different types and sizes of machinery were represented in the power station.

While a large quantity of some of the finest steam coal on the coast is mined within sixty miles of Vancouver, and notwithstanding the fact that the city has every natural advantage for obtaining a good supply of coal at reasonable rates, monopoly decrees otherwise, and in consequence at an early date investigations of the possible sources of hydraulic development in the neighboring mountains were commenced. Measurements of three available streams, Seymour Creek, Coquitlam and Stave Rivers, were taken at intervals, but, owing to the very large investment required for the develop-

ment of hydraulic power on any one of them, and the comparatively small market afforded by the city of Vancouver, ten years elapsed before threatened competition awakened the electric interests to the necessity of taking immediate action as a measure of self-protection. Not until this time were the wonderful possibilities of development exemplified in the present plant of the Vancouver Power Co., Ltd., fully realized.

Early in 1902, a very careful examination and report was made upon the relative advantages of Coquitlam and Stave Rivers as sources of hydraulic power, and upon the general method and cost of the proposed development. Upon the basis of this report, which called for an expenditure of approximately $1,000,000, the undertaking was financed by the British Columbia Electric Railway Co., representing the electrical interests in Vancouver, and on the 15th of August, 1902, construction was commenced.

Reference to the accompanying maps makes clear the general plan of the development, the chief features of which are the dam at the outlet of Coquitlam Lake for the diversion and the creation of storage, a tunnel connecting Coquitlam with Trout Lake and serving as a water conduit, a dam across the outlet of Trout Lake and pipe lines from this dam to the power station, situated on a navigable arm of the sea, just above high tide.

Coquitlam, the main source of supply, is a glacial lake, having an area of 2,300 acres at an elevation of 432 feet above the sea level. The drainage area is approximately 100 square miles, and the annual precipitation over this area is about 150 inches. Measurements of the flow taken at the outlet of the lake over a period of thirteen years, show that the lowest stage of water ever recorded occurred in September, 1904, when the flow was 300 cubic feet per second for a period of nearly fifteen days, gradually increasing until on November 30th the flow was 5,000 cubic feet per second.

Trout Lake, used as a balancing reservoir at the head of the pipes lines, is separated from Coquitlam by a mountain range rising 4,000 feet above its waters, and the horizontal distance between the

two nearest points of the two lakes is 12,775 feet, or nearly two and a half miles. The lake is situated close to the north arm of Burrard Inlet, and is distant about sixteen miles from the city of Vancouver. Its area is approximately 500 acres, and its elevation above the sea level 400 feet, making the difference in elevation between Trout and Coquitlam lakes exactly 32 feet.

Owing to the steep, rocky slopes and perpendicular cliffs of the mountains separating the lakes, it was found impracticable to carry

TROUT LAKE DAM.

the line of levels over the range, and accordingly four series of levels were run from portal to portal of the proposed tunnel, a distance of twenty-five miles around the end of the range, with the remarkably small maximum variation of 0.23 foot, determining the difference in elevation of the two lakes.

For the alignment of the tunnel a Buff transit was used, having a large, high-power telescope. The instrument proved most satisfactory, and no trouble was experienced in setting points 9,300 feet

distant. For convenience in communicating between the different stations, three signal men from the local militia were employed using flags and the usual code, which method was found to be a great aid.

Four stations were established, of which two were on the mountain, 3,200 feet apart, one on the further shore of Coquitlam Lake, and one on the further shore of Trout Lake. From the station on Coquitlam Lake to the summit of the mountain the distance is 7,901 feet, from the summit to the lower station on the mountain 3,203 feet, and thence to the Trout Lake station 6,170 feet. Owing to the contour of the mountain sides, neither tunnel portal could be seen from the stations on the range, and it was therefore necessary to produce the alignment back across the lakes.

When both ends met the closing error in alignment was found to be only seven-eighths of an inch, and the error in the levels only $1\frac{3}{4}$ inches.

In August, 1902, temporary camps were established at each portal of the tunnel, and the work of clearing the extremely heavy timber commenced. During September open cutting at the portals was carried on by driving temporary headings through the gravel and clay deposits and then breaking down from above. At the Trout Lake heading solid rock was found at a distance of 120 feet from the shore, and at Coquitlam only 80 feet of open cut was necessary.

Hand drilling was employed at each heading until January of 1903, when the installation of compressor and haulage plants at both portions was finally completed.

Owing to the uncertain nature of the work, it was decided after an examination of the tenders on tunnel work to let the contract on a percentage basis, based on a sliding scale in which the contractor's profits are increased in proportion to the decrease in cost per foot from the tendered price and an independent bonus provided for speed.

From an engineer's standpoint this form of contract is advantageous, since it places him in complete control of the work that ordinarily falls to the contractor.

The tunnel construction plants were furnished by the Vancouver Power Company, and the following grades were adopted for drainage and haulage: From the Trout Lake portal the tunnel has a rising grade of 0.14 per cent. for 6,300 feet, and thence a decline of 0.02 per cent. for 5,600 feet to the drainage sump, where the pumping plant was located. From thence a rising grade of 6 per cent. for 875 feet to the Coquitlam portal.

A short line of thirty-six inch gauge railway was run from salt water to the Trout Lake tunnel portal, the first section of which is 1,800 feet in length, and has a rise of 400 feet. This portion is operated by a Lidgerwood hoist having a pull of 2,000 lbs., while the balance of the road is level and is operated by an electric locomotive.

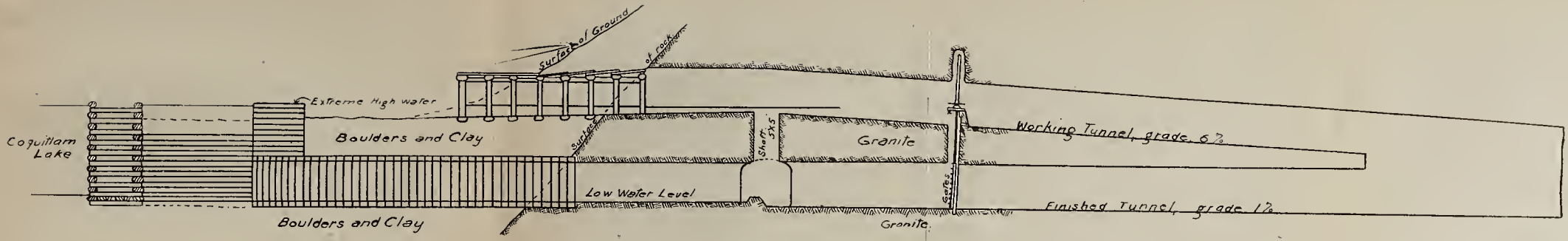
The tunnel plant at the Trout Lake portal consists of an eighty horse-power brickyard type boiler, an Armington and Simms high-speed engine, driving a sixty kilowatt direct current 550 volt generator, supplying current for lights, ventilating motors and electric haulage, and a Leyner two-stage air compressor, having a capacity of 400 cubic feet of free air per minute. At the Coquitlam portal a duplicate plant was installed with slightly greater boiler capacity in anticipation of pumping as the work progressed. For the transportation and installation of the latter plant it was necessary to build two miles of new road through a dense forest and swamp and to rebuild seven miles of old road and bridges. Of the nine miles of road nearly four miles were corduroyed, owing to the boggy nature of the ground.

The normal sectional area of the tunnel is seventy-three square feet, the section being 9 x 9 feet, with rounded corners. The method of procedure in attacking the face or heading was as follows: A tunnel bar five inches in diameter and nine feet in length was first set in position across the tunnel and about three feet below the roof, the miners standing on the muck of the previous blast. From this position of the bar, three back or upper holes, four breast holes and four cut holes were drilled. The uppers were dry holes and formed the roof. The breast holes were wet holes, i.e., having a slight dip below the horizontal, and the cut holes had a slope of

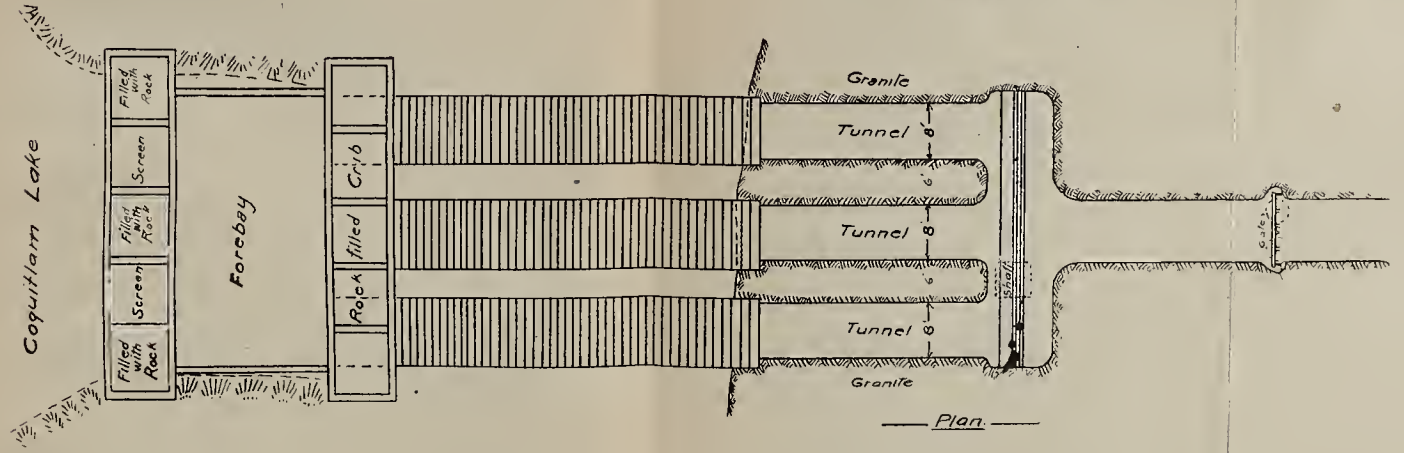
about 30 degrees below the horizontal. While these holes were being drilled, the muck from the previous blast was removed and the bar then lowered, and four "lifters" drilled under the bar to take out the floor to grade. During the time the miners were drilling the "lifters," the muckers laid mucking plates of quarter-inch iron about four feet square on the floor of the tunnel for a distance of thirty feet back from the face, removed dull steel and cleaned up for the blast. The iron plates afforded a suitable floor for shovelling the broken rock after a blast and greatly facilitated the speed of mucking, which work was done by nine men working three eight-hour shifts, two men shovelling at a time and one resting. About sixty tons of rock were removed each twenty-four hours.

Besides the compressor, a receiver having a capacity of 100 cubic feet of air was provided at each portal, located just outside the tunnel. Four-inch standard pipe was used underground for a distance of half a mile from the receivers and three-inch pipe for the remaining distance, with about 200 feet of two-inch pipe as temporary connection between the three-inch pipe and drills. To overcome the trouble due to wet air, short drops were placed at one-half mile intervals in the air line, and drip cocks on the pockets were left "cracked" to expel the condensed moisture when trapped. Flanged unions were provided at 500-foot intervals to facilitate repairs, and all joints were made up with oil and graphite, the pipe threads being run over with a die before taking the pipe into the tunnel. With sufficient care in making the joints no leakage was apparent.

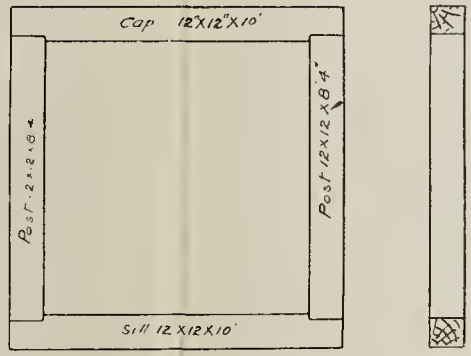
The work was started with four three and one-quarter inch Little Giant rock drills at each heading, two being constantly in service, and two in the repair shop or ready for use. These were used for nine months with an air pressure of 100 lbs. per square inch. As work progressed the rock became harder and larger drills, three and five-eighths inches in diameter, and seven-inch stroke, of the same type, and using 100 lbs. pressure, were installed. A number of different types of drills were tried on the work, some of which gave excellent results, but the Rand Slugger drill with piston



Section of Intake and Protection Works.
Coquitlam Lake Portal.
Coquitlam Tunnel



Plan.



Detail of Timber Sets.

valve proved preferable to the miners and these were finally adopted. Speed being an important factor in the work, the drills were worked to the utmost limit, and the cost of repairs has been comparatively high per foot advance. The policy of keeping machines in the best possible condition had been constantly followed, and in December, 1904, new shells, cylinders and pistons were provided for each machine. Experience on the work has shown that the useful life of a machine drill under the conditions obtaining is at most twelve months, and resembles the old maid's stockings, which she wore for five years—repairs, five new feet and two new legs.

The shanks of the drills used were of one and three-eighths-inch Octagon Crescent or Canton steel, fitted with one and one-eighth inch bushings for the chucks. The bits were welded to the shanks and made of cruciform steel, varying from one and one-quarter inch to two and one-quarter inches in diameter, and swedged out to from one and one-half inches to two and one-half inch bits in one-quarter inch variations. Drill sharpening was done by a blacksmith and helper at each heading with the use of special tools. Tempering was done by cold running water and also by dipping in a mixture of prussiate of potash and water, followed by a plunge in cold water. Good results were obtained by each process, and under ordinary conditions each steel will drill from eighteen to twenty-four inches with one sharpening.

On an average 120 drills were sharpened per day with the use of 100 lbs. of blacksmith coal.

Owing to the fact that cars of sufficient capacity capable of being dumped by one man could not be obtained, special cars were designed and built. These have a height of only thirty inches above the rail and a capacity of two cubic yards. The bodies are of steel and swing on a centre king-bolt, dumping out of one end and on either side of the track. The cars weigh 1,500 lbs. and are equipped with twelve-inch, standard pattern chilled wheels, pressed on to two and one-half inch axles. The cost of the cars was $130 each.

A General Electric locomotive with double equipment, consisting of two ten-horse power, 500 volt motors, and series-parallel

control, having a draw-bar pull of 1,200 pounds, was provided for haulage at each heading. Each locomotive readily handled two loaded cars on a six per cent. grade, developing thirty-two horse power for about a minute and a half. They were worked at a speed of from four to six miles per hour and proved eminently satisfactory, costing very little for repairs. Two motormen working twelve-hour shifts handled the cars from the face of the tunnel, dumped them and loaded all sharp steel taken into the tunnel.

As the tunnel penetrated the mountain, the question of ventilation had to be met, and a solution was reached by the installation of a twelve-inch galvanized iron pipe of number twenty-four gauge, at a cost of 7½ cents per pound. Forty-inch Sturtevant fans, driven by five-horse power motors, were placed at 2,000-foot intervals, working in series, each fan forcing the air to the next one in the line. The speed of the fans was between 1,300 and 1,400 revolutions per minute, and served to clear the tunnel of gas and smoke in forty-five minutes after a blast. At the same time compressed air was blown through a one-quarter inch opening into the face and aided in forcing the gas back to the end of the twelve-inch ventilating pipe, which was kept about 100 feet away from the face, out of reach of flying rock and debris. As the ventilating pipe was subject to extremely heavy concussions, a very strong and rigid plan of holding it in place had to be adopted.

Several methods of lighting the tunnel were tried, but all were abandoned in favor of candles, which, though expensive, were best suited to the miner's requirements. The plants and camp buildings were all electrically lighted.

The fuel item for camps and plants proved expensive, owing to the difficulty of landing the wood at point of use. At the Coquitlam portal, logs were felled into the lake from the shores and towed to the vicinity of the camps, where they were cut up into four-foot lengths while in the water and then hauled out on an incline by means of the electric locomotives and steel blocks with wire cable. Sawing was done with a drag saw driven by a five-horse-

power motor. At the Trout Lake heading the logs were hauled out with a donkey engine and hand sawn.

The working tunnel floor was begun at the Coquitlam portal at an elevation of five feet above high water level in the lake, for safety during construction. During the progress of the tunnel proper, a shaft was sunk in the floor of the working tunnel at a point thirty feet from the portal, to a depth of eighteen feet, the floor level of the finished tunnel. From the bottom of the shaft, a cross cut, or heading, was run at right angles to the tunnel for a distance of twenty feet on each side of the centre line. The cross section of the heading is ten feet by ten feet, and from it three eight-foot by eight-foot openings, parallel to the tunnel, were driven into the lake, forming a submerged intake. From the centre of the cross-heading and directly under the upper working tunnel, the finished tunnel was driven on a one per cent. grade to meet the former, which has a grade of six per cent. to the portal. While this necessitated the driving of some 300 feet of extra tunnel, it insured freedom from lake water and interruption to the work. During construction, and until the tunnel headings met, about ten feet of rock was left in place in each of the three intake tunnels to guard against flooding.

For control of the flow of water through the tunnel two gates are provided in the main tunnel at a distance of sixty feet from the Coquitlam portal. The upper, or working tunnel, has been converted into a gallery from which the gates are operated by means of screw stems, ball bearing nuts and hand wheels, resting on a framework fastened rigidly to the rock by anchor bolts, while all the spaces between frame and rock are filled with concrete for water tightness. The gates are each four and one-half feet by nine feet, built up of structural steel and carrying on each side brass rollers, running on "I" beams, which form the framework. The gates carry flanges on each side, which seat only when the gates are closed.

The formation of the mountain mass pierced by the tunnel consists essentially of syenite or quartz syenite, a granitoid rock,

consisting of quartz, feldspar and horn blende, with occasional dykes of diorite. The rock increased in hardness from the surface and the diorite was found invariably hard and tough. The structure was very uniform and hard, no timbering being required on the entire length of the tunnel.

Temperature readings were taken at each 1,000 feet advance and showed a rise of only two degrees for each reading. The maximum temperature of sixty degrees F. was reached at a distance of 3,500 feet below the surface and 6,000 feet from the portal.

The dam at the outlet of Coquitlam Lake is a rock-filled timber crib structure.

The cribwork is made of twelve-inch by twelve-inch sawn timbers, placed six to seven feet apart, centre to centre, and drift bolted together with three-quarter inch drift bolts. The apron consists of twelve-inch by twelve-inch by thirty-eight-foot timbers drift bolted to twelve-inch by twelve-inch sills, and also drift bolted to one another laterally. Below the main apron there are two smaller ones, one on each side of the river, which protect the abutments and prevent any undermining from the action of the water.

The river bottom on which the foundation rests consists of a pavement of large boulders, underlying which is glacial hard pan.

Along the upstream toe of the dam these boulders were removed and a trench dug into the hard pan; a double row of sheet piles was then driven along this trench and spiked to the twelve-by-twelve timbers, the trench being refilled with the best available material, well rammed. The top sheeting consists of a double thickness of planking, the bottom planks being four inches, and the top ones two inches in thickness. The length of the dam is 113 feet and its height is 14 feet. The top width is 12 feet and the width at the base 50 feet, not including the apron.

The reasons for the unusually extensive apron to this structure will be better understood when it is known that at flood water large fir and cedar drift logs six to eight feet in diameter pass over the dam.

The dam was built by day labor, except the sawing of the timber. This was all cut near the dam site at a cost of $15 per thousand board measure and consists chiefly of hemlock.

A portable sawmill was erected at a point about 700 feet upstream from the dam, and the sawn timber was dumped into the stream and floated down to the work, where it was picked out of the water by derricks (one on each side of the river), put into place by only one handling and immediately drift bolted.

The derricks were operated by a donkey engine and were used also in placing the rock filling in the cribs.

The total amount of timber used in the structure was 600,000 feet board measure, and the cost, including the intake crib and head gates for the City of New Westminster water pipe, was $25,000.

As there was not sufficient rock to be had in the immediate vicinity of the dam to complete the filling, a quantity was brought from a point upstream, where a quarry was opened and a short tramway built to haul the rock to the dam.

The work was only partly finished the first season, as its completion would have flooded the tunnel. The abutments, foundation timbers and aprons were put in and covered over with temporary planking. This planking was removed and the rest of the work completed after the tunnel was finished.

The dam across the outlet of Trout Lake was built by day labor, and is located at a point where the creek passes through a deep ravine about half a mile from the lower end of the lake.

Before deciding upon the location, a large amount of preliminary work had to be done in order to ascertain the nature and exact position of the underlying bedrock, which was covered over with a thick variable stratum of hardpan. This hardpan had to be drilled and blasted, and owing to the numerous large boulders it contained, was difficult material to handle.

Ten shafts were sunk through the hardpan, varying from twenty feet to fifty-four feet in depth, and connected by drifts running along the bedrock.

When the final location was decided upon, the site, which was covered with a dense growth of large fir and cedar timber, was cleared and a temporary dam built at a point about 100 feet upstream. This dam was a long crib structure with a rock filling about twenty feet in height and cost $1.00 per cubic yard of contents. It was necessary to give it sufficient stability to withstand flood water, which at one time passed over its entire crest.

A flume was built from this dam and extended down along the creek bed for about 600 feet, past the site selected for the permanent dam.

In order to make the excavation for the permanent dam, a donkey engine and large boom derrick were installed on each side of the creek, and as the material was excavated it was dumped into the flume by means of the skips and sluiced away. All large boulders met with were picked up and placed to one side and afterwards used in the concrete filling.

In this way 20,000 cubic yards of material was removed, most of which passed through the flume, being handled only once.

This ground was of such an exceptionally hard nature that no impression could be made upon it with picks, so that it had to be drilled and blasted. Some of the boulders met with were very large, containing as much as five cubic yards, and at first were mistaken for bedrock.

After the excavation was completed the surface of the rock was washed clean and carefully examined for the entire length of the dam and all loose pieces and partially decomposed rock removed. It was found to be syenite of a good sound nature and most favorable for the foundation of a dam.

The bedrock, after being thus prepared, was drilled with small holes six inches deep, and three feet apart, which were loaded and fired, producing a rough surface, such that a good bond would be made with the concrete.

In building the base of the dam no forms were used, but the entire width of the excavation was filled in with concrete, and

brought up to a level surface, after which the form timbers were put in place.

The concrete consisted of one part Portland cement, two and one-half parts sand, and five and one-half parts crushed granite.

Along the upstream face of the dam a little different mixture was used for a thickness of about eighteen inches. This contained more cement, the object being to secure water-tightness.

The concrete was mixed with a gravity mixer, which emptied into a skip. It was then removed with a derrick and placed in the work. The mixer was hung on rollers and did duty for skips which it filled alternately.

The concrete was placed in the dam in layers about ten inches in thickness, and so built up that frequent jogs or offsets were left to make a thorough bond with the following course.

Before commencing a new course, the top of the foregoing one was roughened with picks and then washed off clean with a hose. The concrete was then put into place and trimmed with shovels and well tamped.

It was found that the best results were obtained when the concrete was made rather wet; this was especially the case when boulders were placed into the work. The concrete work was carried on day and night, and was completed within five months of its commencement. Were it not for the fact that it was impossible to get sand delivered to the work in sufficient quantities to keep the entire force of men employed, this work could have been completed in a much shorter time.

In one ten-hour day shift 105 cubic yards were placed, and in one nine-hour night shift 87 cubic yards, making a total of 192 cubic yards of concrete work in one day.

The sand used came from the sea bottom near the mouth of the Fraser River, where it was pumped on to scows and then towed to the landing, where it was loaded into cars, hoisted up the hill by

means of a steam hoist and delivered to the dam, where its cost amounted to about $1.00 per cubic yard. This sand, although not coarse, was very clean and sharp and produced first class concrete.

The rock used in the work was quarried out of the hill side at a point about 300 feet from the work. It was loaded into cars and landed at the crusher by means of a small gravity tramway. The top of the dam was built up to the level of Trout Lake. It has a length of 361 feet and a maximum height of 54 feet. It has a width of 35 feet at its base, and a top width of 7 feet, and contains 10,000 cubic yards of concrete.

There are ten fifty-four-inch steel pipes and two twenty-four-inch pipes penetrating the dam at a point twenty-two feet below its top. These pipes are all fitted with special roller gate valves at the face of the dam, with separate screens for each pipe.

Four different brands of Portland cement were used in the work, viz., White Bros., Hercules, Condor, and Alsen.

These cements were all tested as the work progressed, each shipment being sampled.

There were 12,400 barrels of cement used in the dam at a cost of about $3.50 per barrel delivered at the work.

The excavation cost $1.00 per cubic yard and the concrete work $8.50 per cubic yard.

The cost of the work was made considerably greater than it otherwise would have been on account of the high rate of wages for common labor which prevailed, and the poor class of labor available. The night work also added to its cost. The sand had to be pumped from the sea bottom, and in rough weather it was impossible to get it delivered fast enough to keep the force employed.

The intake gate valves are placed in guides bolted to the face of the dam and are fitted with brass rollers, on which the thrust due to the water pressure comes. A circular ridge on the back of the gate is machined to make the seat and a corresponding seat is

VANCOUVER POWER CO. LTD.

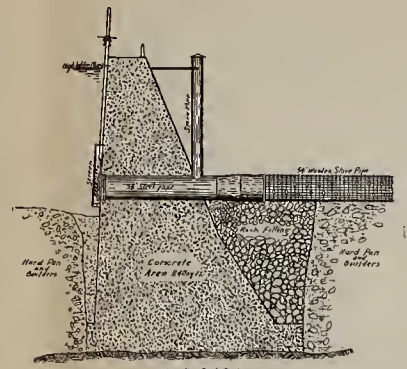
CONCRETE DAM

AT

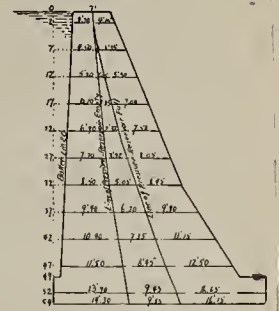
OUTLET OF TROUT LAKE

Total Excavation in hard pan and boulders 20,000 cub yds.
Total Contents of Dam 10,000 " "
Total Quantity of Portland Cement Used 12,900 barrels
Brands, White Bros Alsen, Condor, Hercules,
Concrete composed of
1 Part Cement, 2½ Parts Fraser River Sand, 5½ parts Crushed Granite
Specific Gravity of Concrete - 2.35
Factor of Safety 2.33

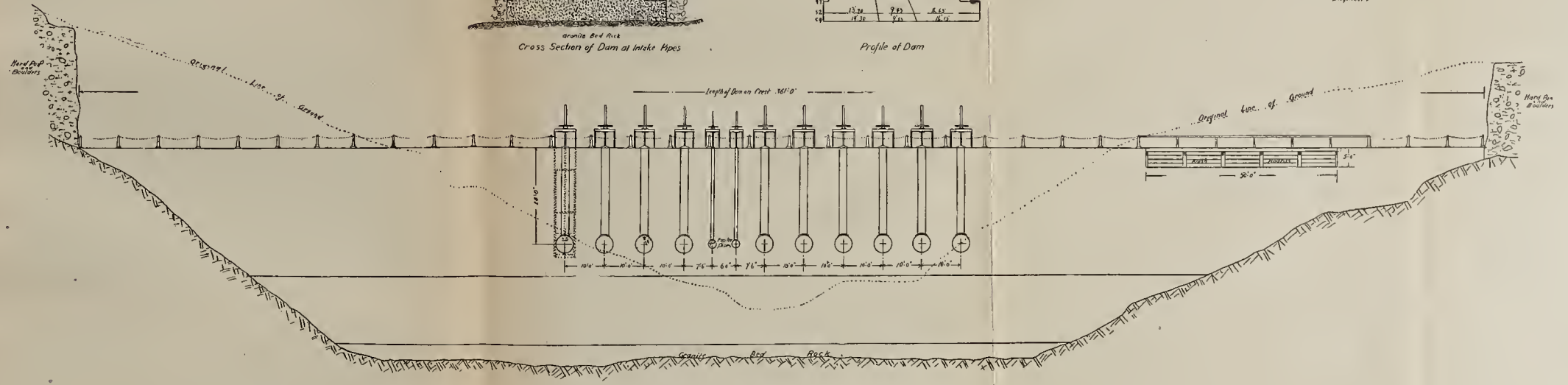
W Meredith
Consulting Engineer
E B Hermon
H M Burwell
Engineers



Cross Section of Dam at Intake Pipes



Profile of Dam



Elevation of Dam showing Rear Face

N°185

made on the gate frame, to which the pipes are riveted. These seats are not quite parallel to the plane of the rollers, so that when the gate is lowered to a certain point it takes its seat and the pressure on the rollers is relieved, but immediately the gate is raised a fraction of an inch the pressure comes on the rollers again. The gear for operating the gate is a simple screw stem and hand wheel, with roller bearing which takes the pull. The gates are quite tight and can be operated with ease by one man at all stages of the water.

FIFTY-FOUR-INCH WOODEN STAVE PIPES. SPIRAL CURVES.

There are fifty acres of land lying between the dam and the lower end of Trout Lake, which have been flooded, and a central canal about fifty feet wide and twenty feet deep was excavated, connecting the new lake with Trout Lake. This gives a reserve or storage of water of about sixteen feet in depth over an area of 500 acres, which can be utilized when required, and forms a balancing reservoir.

This enables the attainment of very high peak loads and reduces the waste of water to a minimum, for immediately the water is shut off at the power house it commences to store in this reservoir instead of running to waste.

The pipe lines extend from the dam to the power house at sea level, for a total length of 1,800 feet, and are built to curves and tangents both vertically and horizontally, no angles being allowed.

The pipe line was graded and the pipes laid in the trench by day labor ready for riveting. The pipes were made and riveted together on the ground by the Vancouver Engineering Works, Ltd., of Vancouver, B.C.

The first trench excavated was made to accommodate five pipes; it passed over a vertical rock bluff seventy feet in height which had to be cut down, and at the lower end in order to extend the pipes into the power house it was necessary to put two short tunnels through the rock, 110 and 135 feet in length, respectively. These tunnels were built in curves with 200 feet radii.

On one portion of the pipe line, where a creek is crossed at the foot of the bluff, it was necessary to lay the pipes on temporary trestles, which were constructed to suit the vertical curves taking place at these points. The trestles afterwards were used as false work, when they were finally replaced by concrete piers.

A tramway was built in the pipe trench for its whole length and operated by a steam hoist. In this way all the pipes were put in place, the track being shifted over laterally as each line of pipe was placed.

The average depth of the trench excavated was six feet, and the bottom was brought to an even surface. This enabled a track being laid along it, and greatly facilitated the handling of the pipes, and the building of the lines.

The material excavated was afterwards used to cover the pipes, all the rock being hand placed under the pipes, and the whole work covered up with the finer material and sown over with clover seed.

Where curves occur at the lower end of the pipe line, the pipes are kept in place by concrete piers set from twelve to sixteen feet apart.

The upper portion of each pipe line is of wooden stave construction, fifty-four inches in diameter, and extends from the dam for a distance of 800 feet to a point where it is under pressure due to seventy-five feet head. From this point to the power station the pipe lines are of riveted steel, varying in thickness from nine-thirty-seconds inch to seventeen-thirty-seconds inch and ranging in diameter from forty-eight inches to forty-two inches at the lower end.

At the present time three main pipe lines and one exciter pipe line are installed, and a fourth under construction, the total length of each of the steel lines being 1,000 feet. Each line is fitted with air valves at three different points, a relief valve at the lower end and a stand pipe just below the dam.

The exciter pipe line is constructed of steel throughout its entire length, and is twenty-four inches at the upper end and eighteen inches at the lower end. The thickness of plate varies from one-eighth to one-quarter inch.

The wooden stave pipes were built by the Excelsior Wooden Pipe Co., of San Francisco, and cost approximately $4.00 per lineal foot, the lumber being delivered at a cost of $37.50 per thousand feet board measure.

The cost of the steel lines was approximately $14.50 per lineal foot for the large pipes exclusive of excavation for the trench, which is 1,800 feet in length and about thirty-eight feet in width. This work includes about 400 feet of trestle and 250 feet of tunnel, also about 3,500 cubic yards of rock work in cutting down a bluff about seventy feet in height. The balance of the excavation was made through large boulders, gravel and hard pan, all of which was overtopped with a dense growth of immense cedar and fir trees.

The cost of the pipe line grading, including the hand placing of broken rock around the pipes, back filling, concrete piers and anchorage, amounted to about $25,400.

In designing the Vancouver Power Company's installation, the present demand for electric power, as well as the natural annual increase as shown by the records of the station, was considered. Accordingly, it was decided to instal the initial equipment for 9,000 horse power in three units. Convenience of handling and independent unit operation favored separate pipes lines. Each unit consists of one revolving field engine type 200 revolutions per minute, three phase, 2,300-volt Westinghouse generator, and two Pelton water wheels, one on either end of the shaft, taking water from a single pipe through a Y-connection and two deflecting needle nozzles, one to each wheel; the shaft bearings and bed-plate being furnished by the water wheel makers. The needles are adjustable by hand to suit the maximum fluctuation of load and the nozzles deflected by type Q Lombard governors.

The revolving fields were especially designed and constructed to withstand a runaway speed which might accidentally reach 175 per cent. or more. The hollow forged steel shaft carries the rotor centrally between the bearings, making a perfectly symmetrical arrangement and loading the two bearings equally.

Spatter water from the wheels is caught in a housing pocket and passed through the hollow shaft and also through the oil cellar of the bearings. The rotating element, including shaft wheels and field, weighs 80,000 pounds. The water circulation system has proved of great value in maintaining cool bearings.

Exciting current is provided by means of either one of two direct connected water wheel driven generators, coupled to an induction motor, taking current from the main bus bars. The motor not only insures exciting current in the event of wheel troubles, but serves as a governor absorbing as a generator the power of the wheel in excess of that required by the exciter.

The equipment is housed in a plain massive granite building, 40 feet in width and 160 feet in length, located just above high tide. As the granite bluffs extend almost vertically from the water edge, it was necessary to excavate a sort of shelf, not only for the

present building, but for such future extensions as may be necessary to house the apparatus for an ultimate capacity of 30,000 to 40,000 horse power. Much of the excavated rock was landed directly in the water by the force of the blasts, the water immediately in front of the works being over 600 feet in depth.

Foundations are provided for the addition of a fourth unit of similar size and design; beyond this only excavation for power house

GENERATING STATION.

extension has been provided. It is probable that further additions will consist of 6,000 horse power units or larger.

The switchboard is located upon a raised platform at one end of the building, affording the operator a complete view of the main floor. The board is of the usual construction, equipped with Tirrill regulators, a full set of indicating and recording instruments and automatic oil switches. Two sets of bus bars are provided, one for the constant lighting load and one for the variable railway and

power service. Two single throw switches are used in place of the usual double throw switch, one connected to each set of bus bars. This permits of transferring a generator from one bus to the other or feeding them in parallel without opening the circuit, thus providing great flexibility and insuring smooth service.

In a concrete building on a small flat just above and back of the power house is installed the step-up transformers, high potential switches and lightning arresters. There are three sets of three 550-kilowatt air blasts, delta connected, transformers raising the voltage to 23,000 for transmission. The low potential side of these transformers is controlled by switches located on the main switchboard in the power house. The high potential side may be connected to either or both of two sets of bus bars and the four transmission circuits may in the same way be connected to either or both sets of buses.

The many switches required for this multiplicity of connections are of special design, made at the company's works, and are perhaps of more than passing interest. They are of the bayonet air break type, and contain no oil. When a switch is closed the bayonet compresses a spring behind a piston which furnishes a slight blast of air at the precise moment the bayonet is withdrawn, thus blowing out the arc before any considerable metallic vapor is formed. The arc appears to be about one and one-fourth inches in length when breaking a 2,000-kilowatt 23,000-volt circuit. Westinghouse low equivalent lightning arresters are connected to each line, which is also provided with an ampere meter and a potential tell-tale.

Immediately outside of the transformer building there is inserted in each line a set of ram's horn emergency switches, which are operated from either in or outside points.

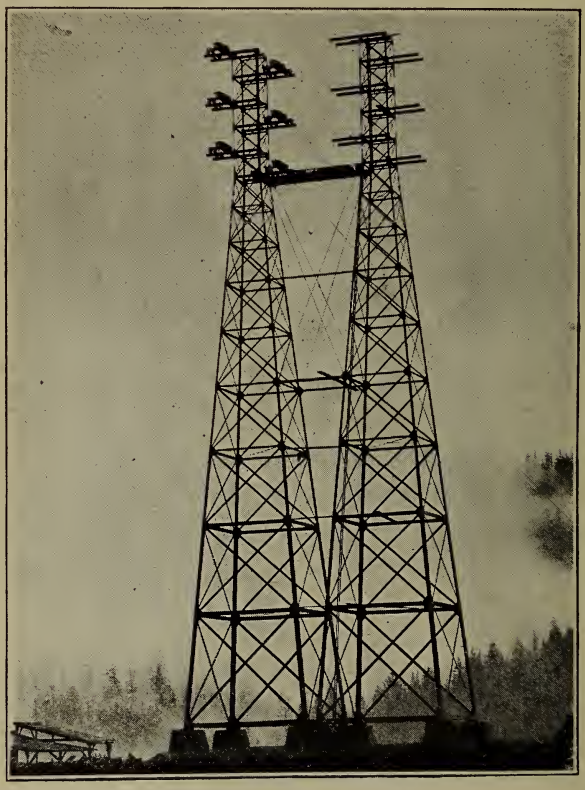
The double forty-five foot pole line carries four three-phase, No. 2 B. & S. gauge, medium drawn, copper circuits, two on each line. The wires are supported on nine-inch umbrella type Locke glass insulators, mounted on a special metal pin. At corners and points of extra strain the insulators are provided with a cast iron cap cemented on. The clearing of the right-of-way through the

extremely large timber of the dense forest, characteristic of this locality, was an expensive piece of work, not usually met with in transmission line connection. For 100 feet in width the right-of-way was slashed, the brush and tops being burned and the immense logs rolled to either side. Outside of the 100 foot line all trees that might reach the line in falling, and there were many of them over 200 feet in height, were cut. The line from the power house to the Barnet crossing is built over a rough mountainous country, where wagon roads are impossible. Fortunately, there was found magnificent cedar growing on or near the right-of-way, from which all poles were cut. The cost of clearing alone amounted to $860 per mile.

At Barnet the lines cross a navigable arm of the harbor. The distance between supports is 2,750 feet and the conductors are 150 feet above high tide at the lowest point. Twelve seven-strand nine-sixteenth-inch galvanized plow steel cables are used as conductors. High ground on the north shore and twin towers on the south shore form the supports of the doubly insulated saddles holding the cables. Each cable is anchored to eye bolts at either end. These are sulphured in solid rock on the north end and secured to a concrete monolith at the south end. Anchorage insulation for each cable is secured by means of a series of thirty-two of the nine-inch, glass, line insulators, which are provided with cemented iron caps and supported by metal pins held in a double angle iron frame. The insulators are mounted in pairs, the cable passing between them. The strain is transmitted to the insulators by means of a clamp on the cable behind an equalizing bar, which transmits the strain to an insulator on either side, equally distant from the cable, by means of two U bolts having a curve of slightly greater radius than the neck of the iron insulator cap. This design permits the use of ordinary line insulators for almost any span, and it is worthy of note that any insulator can be replaced quickly and without difficulty.

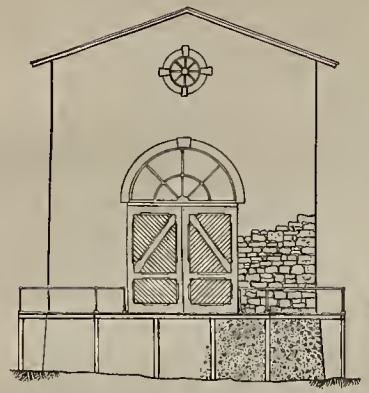
From Barnet the line is constructed along the highway almost due west nine miles to Vancouver. Three miles from Barnet one

line runs south to the Barnaby sub-station, located on the tramway connecting the city of New Westminster with Vancouver, and thence along the railroad right-of-way to Vancouver, forming a loop. In this way the Vancouver and Burnaby sub-stations are served by two independent pole lines and four circuits.



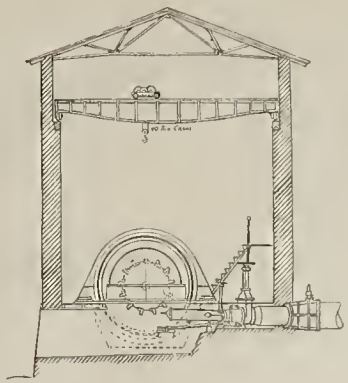
CABLE CROSSING — BARNET.

A four-mile branch line from Burnaby to a sub-station in New Westminster supplies the municipally owned distributing lines with current for both incandescent and street arcs. From Vancouver a branch line extends seventeen miles to the delta of the Fraser River, where another sub-station is located that supplies current for the Lulu Island electric road and lighting and power service-

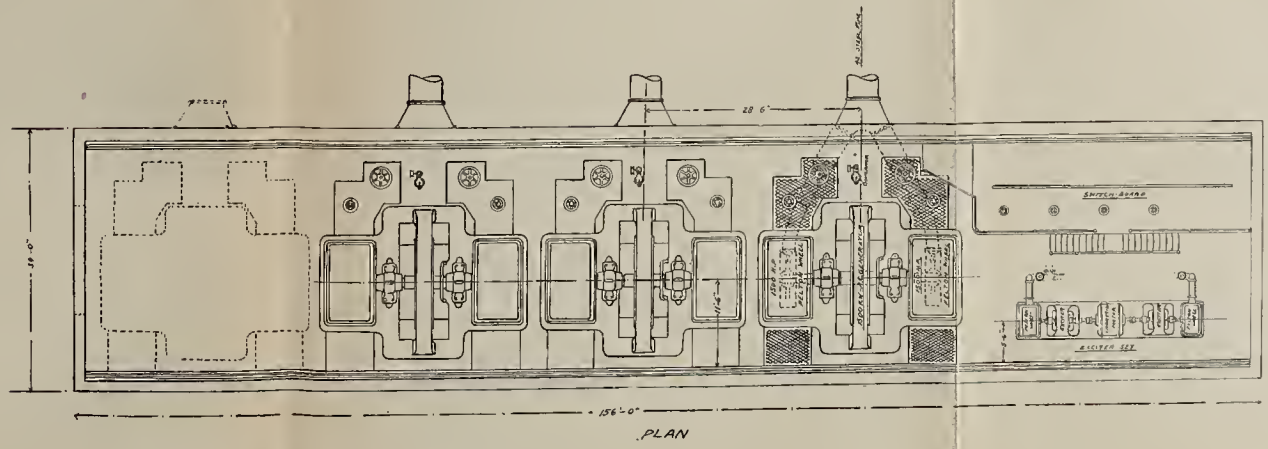


NORTH ELEVATION

SECTION & WEST ELEVATION



CROSS SECTION



PLAN

VANCOUVER POWER CO
LIMITED

GENERATING STATION
AT

TROUT LAKE

Scale. ½in. = 1ft. Vancouver, Dec. 8th 1904.

W. Meredith
Consulting Engineer.
E.B. Hermon
H.M. Burwell
Engineers

for Stevetown and Ladner, where the large salmon canneries are located. All sub-stations are of steel and masonry construction, designed for small fire hazard and low depreciation.

Transmission lines are all equipped with ram's horn disconnecting switches, located just outside of the buildings and arranged for operation from the inside. Flexibility of connections is obtained by means of a set of single pole automatic air blast switches in each station, which permits of any combination of circuits being made.

VANCOUVER SUB-STATION.

From these switches two sets of high potential bus bars provided with low equivalent lightning arresters are carried to the step-down transformers, which are all of the air blast type.

The Vancouver sub-station is located on Westminster Avenue, one of the principal streets of the city, and is a fine, substantial building 60 x 120, with large plate glass windows facing the avenue. In addition to the basement and main floor, there is a steel and concrete floored gallery, eighteen feet wide on the front and both

sides. The air blast switches occupy the front portion of the gallery and the lightning arresters and transformer switches are located on one side, the railway switchboard being on the other. Spiral stairs give ready access to the gallery on either side. The open space in the middle is reserved for rotary converters, and is provided with a hand-operated bridge crane travelling the length of the building.

INTERIOR—VANCOUVER SUB-STATION.

Railway current is provided by means of two 500-kilowatt and one 1,000-kilowatt rotary converters, with their complement of transformers, regulators and switchboard. Each rotary is provided with a direct connected induction starting motor and a direct current rheostatic starting equipment. The switchboard contains both alternating current and direct current rotary panels, a totalizing panel and feeder panels.

The lighting and power service in Vancouver is supplied by means of eight 500-kilowatt step-down transformers, "Scott con-

nected," for two-phase, 2,300 volts. Current from these transformers is taken through a sixteen-panel switchboard, provided with a full complement of instruments and switches. The single-phase feeded circuits are each provided with a double-throw oil switch for connection to either phase for balancing purposes, a time limit controlled oil circuit breaker and independent regulators. Recording voltmeters are used on each feeder, taking current from a pair of pressure wires connected at the centre of distribution.

The first generator was started, and current delivered, December 19, 1903, water for the wheels being obtained from Trout Lake. The tunnel was completed and water delivered through it June 10, 1905. Commercial service has been given since the first unit was started, only one interruption having been noted to date, and that was caused by one of the large wood rats, which are found in this locality, having attempted to build a nest between two of the anchorage insulators at the Barnet crossing. The iron caps used on the insulators were partially fused, but prevented any injury to the cable. A few moments only were required in which to disconnect both ends of this line, when service was resumed over the three remaining circuits. From this experience it would seem that rats and similar animals will have to be counted a menace to electrical transmission lines, as well as birds.

Simplicity and durability were the chief factors considered during the design and construction of the plant. Its operation to date has demonstrated that in a large measure both have been attained to perhaps a greater extent than has been usual on the Pacific Coast.

The principal contractors connected with the undertaking were: Ironside, Rannie & Campbell, tunnel; Westinghouse Electric and Manufacturing Company, electrical equipment; Pelton Water Wheel Company, water wheels; Lombard Governor Company, governors; Vancouver Engineering Works, pipe lines and head gates; Jno. Martin & Co., insulators; Canadian Rand Drill Company, air drills; Geo. Leyner Company, air compressors; in addition to which a great

Table Shewing Daily Progress of the Coquitlam Tunnel

Coquitlam Lake Heading

Day Ending at Midnight	DAILY PROGRESS		DRILLING							BLASTING			MUCKING			GENERAL WORK								SUPPLIES		
	Advance in Lineal Feet	Excavation in Cubic Yards	Machine Drills in use	Machine Men, Number of	Hours Worked	Helpers, Number of	Hours Worked	Holes Drilled, Number of	Total Depth of Holes Drilled	Powder, Pounds used	Fuse, Feet used	Caps, Number used	Muckers, Number of	Hours worked	Cars of Rock run out	Motor Men, Number of	Engineers Number of	Firemen, Number of	Other labour under ground, No of	Blacksmiths, No. of	Blacksmiths Helpers	Drills, No sharpened	Other labour above ground, No. of	Wood, Cords burned	Coal (Blacksmith)	Candles, No. of
Monday .. 13	6	19	2	12	120			26	143	84	230	23	9	72	31	2	2	1	2	1	1	117	10½	5½	119	103
Tuesday .. 14	10	32	2	14	120			26	143	122	440	44	9	72	25	2	2	1	2	1	1	122	10½	5½	119	103
Wednesday .. 15	10	32	2	14	120			34	187	171	450	45	9	72	34	2	2	1	2	1	1	127	10	5¾	119	103
Thursday .. 16	10	32	2	14	120			30	165	150	460	46	9	68	35	2	2	1	2	1	1	135	10	5¾	119	103
Friday .. 17	10	32	2	14	120			30	165	170	560	55	9	72	36	2	2	1	1½	1	1	107	10½	5¾	116	102
Saturday .. 18	10	32	2	14	120			28	154	218	590	59	9	72	31	2	2	1		1	1	114	10½	5¾	116	103
Sunday .. 19	10	32	2	14	120			28	154	200	580	58	9	72	33	2	2	1		1	1	133	11	5¾	117	103
	66	211	2	96	840			202	1111	1115	3220	328	63	500	225	14	14	7	9½	7	7	855	73	39¾	825	720

REMARKS: Ground medium drilling, but required a great deal of sheeting

CAR REPAIRS nil

DRILL REPAIRS, ETC. June 13th 1 chuck bolt + nut, 1 oil plug, 1 shaft bar screw, - 14th 1 Standard, - 17th 1 Rocker pin, 1 Slide valve, 1 leather piston packing ring - 1 packing 2 hours, - June 18th 1 Pawl & Spring, 2 pawl bolts, 2 packings 4 hours, 1 hour cutting side rods, 19th 1 pawl bolt, 1 chuck bolt, 1 Standard 2 hours labour

For week ending June 19th 7 am., 1903/4

Wallace Fraser

FOREMAN.

many contracts were placed with local firms for the smaller machinery, supplies, etc. The steel towers and cables used at the Barnet crossing were made in England and brought out via China.

The whole system of this water power development was originated by Messrs. Hermon & Burwell, and the engineering was performed by Mr. Wynn Meredith, Consulting Engineer, and Mr. E. B. Hermon and Mr. H. M. Burwell, engineers in charge of the construction.

RAILWAY SURVEYS.

ANDREW F. MACALLUM, B.A.Sc.

The responsibilities of a railway engineer to his clients or company are as great as those of a trustee intrusted with the investment of others' funds. Upon his opinion and estimates large sums will probably be expended, and for this reason he must be conservative in recommending any investment where the margin of profit is small. The collateral obligations of a company building a railway will very often be sold or subscribed to upon information contained in his report. He will probably have to listen to glowing reports of promoters and speculators if the proposed line be through a settled country. None of these, however, should enter his report until he has carefully investigated and satisfied himself as to their truth.

The railway engineer must remember that his road is to be built for the convenience of the public, as upon that fact will often lie the financial success of the enterprise. A railroad may be built which, according to engineering standards, may be perfect, where the cost per ton mile or car mile is extremely low, and yet be a financial failure, owing to a disregard of public convenience. It is always wise to locate a line as close to an existing centre of population as the engineer dare risk, having regard to the fixed charges which he thinks his road can stand. As a rule, with few exceptions it has been found that centres of population do not transfer themselves for the benefit of the railway, and it is almost certain that in the event of future competition, always favorably looked upon by the public, the road with the most advantageous location will get the most of the traffic.

A line to be a good commercial route connecting various towns can seldom be located in a way that will exemplify ideal physical location. Hence the average engineer has to fight against the tendency to select the route giving the most favorable grades and curves at a minimum cost, his training being along those lines. He must err, if necessary, on the other side, and at probably a greater first cost to sub-grade, get a line that from the commercial point of view is superior.

Some railroad manager has said that railroad engineers seldom think above sub-grade, and give comparatively little thought to the operating maintenance and commercial aspects of the problem This however is hardly correct with reference to the maintenance, but to a large extent holds for the commercial view and is due no doubt to the training of the engineer at college, and possibly for some years following. I have made these remarks to impress the fact, often lost sight of, that a railway is a commercial enterprise and is constructed solely for profit and not to benefit the health of the promoters.

After the engineer has secured all data possible from maps and local sources, he is prepared to start out on his reconnaissance to select a general route between terminals, and sometimes the terminals themselves. This survey, best made on foot, is usually over an area between terminals through which the proposed railroad must pass, and will be of such a nature that he will be able to eliminate several possible routes and restrict the future instrumental work to two or three lines. The engineer must know the country over a wide area between these terminals so that he may himself be satisfied that he has selected the best route or routes. Too great haste in doing this work, often arduous, will mean that he will probably require more instrumental survey later.

There is a practice followed by one or two prominent roads which places one engineer on the route upon reconnaissance, another upon preliminary, and a third following upon the location. This is a most reprehensible practice, for no quantity of notes or topo-

graphy can take the place of an intimate personal knowledge of the problems to be encountered. For this reason the reconnaissance and preliminary should be made by the engineer who is to locate the road. Of course where the survey is for a great distance or to be made in great haste, the former method will probably be adopted, but with the almost inevitable result that the preliminary engineer, and later, the locating engineer, will follow like sheep along the line laid down by the reconnaissance engineer. Unless very exceptional men are in charge of these parties, with less hurrying than is now the practice, the above may be looked for.

It is a well known fact that the most glaring mistakes in location are generally found upon the prairies due either to this practice or laziness on the part of the engineer. If the reconnaissance is to be through a heavily wooded part of the country then the engineer should provide himself with the following instruments which he will find of great convenience, although he may get on without some of them: two pocket barometers, field glass with level attachment, pocket compass and a pedometer that will give approximately the distance covered each day or between known points. A guide should be engaged, one who thinks he knows the whole country and upon whom you can depend to pilot you along the best trails. But it has been the writer's experience that these guides know very little about relative elevations and will probably consider country dead level which will rise or fall on one or two per cent. grades. This is of course a natural defect that must be expected, as probably before you had arrived upon the scene they had never any call upon this kind of knowledge. In regard to horizontal distances, however, these men are generally more reliable. In any event the engineer must not take anything for granted, but prove everything. If the reconnaissance is through an open or farming country, then he may take it for granted that every farmer will carefully point out to him that there is a much better location for a railroad along a certain valley about a mile or two away. The country is full of these amateur locating engineers and they are always heard from.

The reconnaissance engineer should be a man who has had considerable experience in locating and upon construction, for this work requires a higher order of mind than is called for in merely running a line in detail by the use of instruments. The maintenance and operating will depend upon the reconnaissance, and this most important part of the survey should be entrusted only to engineers of proven ability. This is well understood by the older roads, but is nearly always lost sight of upon new roads under new management.

It is an unfortunate habit still in existence, to hurry the reconnaissance survey, and later location survey, with the result that the best line is not always secured. Money spent on thorough surveys is well spent and the older railway managements recognize this. Probably one of the most glaring cases on record happened in Northern Ontario, where a certain road was built fifteen miles into a *cul-de-sac*, all of which had to be abandoned. The reconnaissance engineer should be of sanguine temperament, one who always takes it for granted that no matter how difficult the country may appear, he can find a good line through it.

The first question to decide is what are the controlling points, such as the lowest point in a ridge or mountain, the crossings of large streams or the location of a town through which the road must be built. Once these are secured and noted upon his map, he can decide upon his limiting grades and curvature. He will then have to go carefully over the ground examining the section of country likely to suit these grades or curves.

The ground should be gone over from both directions, as it often has a different appearance when approached from different quarters. Do not adopt too high a maximum grade, as low grades are the most important of all the details, and the cry on all the older roads is now grade reduction. The most troublesome country through which to locate a line is an irregular rolling country having hills and valleys trending in different directions, and it requires a tremendous lot of hard work before the engineer is satisfied that he

has about the best line. There are too many possible lines through this kind of country, and it is here that the experienced engineer will do his best work. Along shores of rivers or lakes there is little or no difficulty, providing the topography taken later on upon locations is accurate. Upon this I will touch further on.

There are some ocular illusions that must be guarded against. For instance, when looking toward a hill the intervening ground will appear level or falling, whereas it is rising toward the hill. Hills at a distance and overlapping will have the appearance of forming a solid ridge and many errors have been made through this cause. A slope will appear steeper than it really is if the observer be looking down it. Heights and distances are estimated more closely on cloudy days, and it should be remembered that distances are less than they appear to be if the observer be looking toward the setting sun.

When the engineer has decided upon the route or routes over which to run preliminaries and has his map marked with all necessary information, he is ready to organize his party for the preliminary survey. The field corps for a preliminary survey on the best roads is now composed of chief, topographer, with his rodman and tapeman, transitmen, leveller, draughtsman, rodman, front and rear chainmen, picketmen, cook, and if in heavily wooded country, about five or six axemen. The day has passed, on the larger roads at all events, when the chief is expected to act as his own draughtsman, and it is quite time that it has. If he has been on the line all day directing the party, he is seldom in fit condition to work over a draughting board for several hours every evening. The chief of party, according to some engineering handbooks, should possess so many qualities that if he had them he would not be in charge of a survey party. He should however know how to handle men, have a knowledge of construction as well as location, and in settled districts know enough to keep to himself, for obvious reasons, the location of the road and stations.

There is a growing feeling among railway engineers that next to the chief of party on preliminary surveys, the first assistant

should be the topographer. The transitman's duties are really not of a very intricate nature, for he simply takes notes of the angles, distances and bearings, as you all know, but a good topographer must know about as much as the chief about the line if he is going to take intelligent topography, especially if the country be very broken. A common error in this work, especially along steep side hills, is not to go far enough out in the deep holes or high enough upon prominent points. It is the cause of much profanity on the part of the chief to find that the topographer stops short just where he needs information concerning some gully or adjacent hill. It may be that he wished to throw his proposed location line on the high ground in order to get material to fill the gully. Later on during location, if this topographer be inaccurate, more time will be wasted re-running lines than would have paid for two topographers. By the usual methods of checking, the transitman and leveller seldom make errors that are not quickly found, but the topographer has the chief at his mercy until the line is run over the topography taken upon the preliminary. Five hundred feet on each side of the line in 5-foot contours should be taken in comparatively level country, but upon sidehill the matter lies with the judgment of the chief of party or topographer, if he has any.

These contours are best sketched directly into a notebook divided into squares each representing a hundred feet and having the centre line down the middle of the book. This method will be found more accurate than by noting distances out right and left with elevations. A hand-level properly handled will give good results, and with the assistance of rodman and tapeman a good topographer should not have any trouble in keeping close to the level party from whom he can get his elevations.

The duties of the transitman, leveller, draughtsman and chainman are well known. The picketman should also be a good axeman to make quickly the hubs, hub-stakes, back-pickets or cross-heads, besides giving line to the axeman. He should also have good judgment in selecting turning points if the chief is not on the line. In the wooded districts it is not at all difficult to get good axemen

so far as mere chopping is concerned, but it requires two weeks' training at least to get the idea out of their heads that they are not cutting out wagon roads and to keep them in line. Every unnecessary tree cut down is so much time lost, for the axemen set the pace for the rest of the party. Another fault is that they usually persist in bunching up and do not line out along a distance say of a hundred feet.

If the chief is ahead most of the time then it is wise to pick out the most intelligent axeman and make him head axeman at a slight increase of salary. If the party is travelling at a good rate a "stake artist" is sometimes necessary. He should be selected from among the axemen. In most cases the picketman can cover this work also if he is at all quick on his feet.

The custom of conducting all preliminary surveys with a transit is not always to be recommended. In case of short trial lines a compass should be used, thus saving much chopping and of course much valuable time.

In settled districts or open country the axemen are not necessary, but an extra man may be required as teamster and to distribute stakes. It is not wise to cut up fence rails for stakes or hubs, if you wish to keep on friendly terms with the local inhabitants or lessen the troubles of the agent who will later purchase the right-of-way.

This staff I have mentioned is a large one, but necessary if the plans are to be kept up to date. The methods followed at the time of the building of the Canadian Pacific Railway and the attendant hardships are no longer necessary in this country unless several hundred miles from the nearest railway. Some of the older generation of engineers yet think it necessary to make martyrs of themselves in a manner that members of no other profession would dream of doing. But the day of the rough and ready man has passed in this country. The engineer has a right to as much comfort and assistance as he may think necessary, and the results will be that the standard of his work will be much superior in every way than

if he tried to do too much and put up with unnecessary hardships. It is not very many years since a topographer was considered necessary, and still fewer, a draughtsman. That the addition of these extra members to the survey party has been a great success both financially and in the amount of work returned, will be conceded I think by every railway engineer.

About 40 feet of one and one-half inch ($1\frac{1}{2}''$) gas pipe in sections of ten feet with one end pointed, should be carried along to test the depth of swamps, proposed crossings of rivers and along the shores of lakes where the embankments may overlie rock at a steep inclination. In this latter case, it is better to shift the line than to take chances upon the possibility of the embankment doing so later on. These soundings can be taken by the leveller and his rodman without much interference with their regular work.

After the engineer has finished his preliminary surveys and has decided upon the best line, he is now ready to begin his location on his plans of preliminaries which, by the way, in order to avoid cumulative errors, should be laid out by the method known as "Latitudes and Departures." He will by this time have projected a paper location and from the contours secured his profile and estimate of quantities. During the survey he has noted the nature of the soil, outcroppings of rock, size of streams, timber, ballast material and everything that may come into the consideration of construction, maintenance and operation. From this information he can form an intelligent idea of the relative values of the different routes. The projected locations will show the lines with curves approximated, and the profile will have grades duly compensated for their curves. If at stations, the compensation should be one-tenth of one per cent. per degree of curve. At other places four-hundredths of one per cent. per degree of curve.

Reversed curves should never be used, but should have, if possible, three hundred feet between transition points. "Broken back" curves also are generally unnecessary, and curves in the same directions should have about three hundred feet between transition points.

Trackmen find difficulty in keeping a one degree curve in line, and a sharper and shorter curve is preferable. A curve should not be less than three hundred feet in length. It is an undecided question with engineers as to which is the better method within certain limitations, that is, whether to put in short tangents and flat curves or longer tangents and sharper curves, the limit of the length of curve being 2,000 feet. Personally, I favor the longer tangent and sharper curve up to six degrees. Curves of three degrees and over should have transitions to the tangents at both ends. In the following table are given the essentials for spirals for chord lengths of 60 feet for curves up to six degrees. Dividing by two will give data for 30 ft. chords or for rail length chords. The table requires

Spiral Table

Curve	Length of Spiral	No of Chords	Length of Chords	Total Angle of Spiral	Deflections BS to BC						Deflections EC to ES					
1° 0'	60'	1	60'	18"	06'						12'					
1°30'	90'	1½	60'	0°27'	06'	13'					12'	29'				
2° 0'	120'	2	60'	1°12'	06'	24'					30'	48'				
2°30'	150'	2½	60'	1°57½'	06'	24'	37½'				21'	54'	1°15'			
3° 0'	180'	3	60'	2°42'	06'	24'	54'				48'	1°24'	1°48'			
3°30'	210	3½	60'	3°40½'	06'	24'	54'	1°18½'			30'	1°21'	2°00'	2°31'		
4° 0'	240'	4	60'	4°48'	06'	24'	54'	1°36'			1°06'	2°06'	2°42'	3°11'		
4°30'	270'	4½	60'	6°04½'	06'	24'	54'	1°36'	2°04½'		39'	1°45'	2°48'	3°36'	4°38'	
5° 0'	300'	5	60'	7°30'	06'	24'	54'	1°36'	2°04'	2°25'	1°24'	2°36'	3°36'	4°24'	5°00'	
5°30'	300'	5½	54½	8°15'	05'	20'	45'	1°36'	2°04'	2°25'	43½'	2°04'	3°13'	4°14'	5°04'	5°30'
6° 0'	300'	6	50	9°00'	05'	20'	45'	1°20'	2°05'	3°00'	1°25'	2°40'	3°45'	4°50'	5°25'	6°00'

no explanation and is of convenient form to paste in the back of a transit book.

On location the transitman's duties will increase, for he will now have the curves to calculate and run in. If in bush country, the method of long chords will be used. The transitions will be located by offsetting.

The notes for the location are calculated from and should not be scaled off the projected paper location. This is where the topographer shows how accurately he has done his work, for, assuming that he has transferred the notes correctly to his note-book, then the profile secured should approximate very closely to that obtained from

the projected location. If you are fortunate in your topographer it generally will, and you will lead a contented life. Otherwise no one should wonder why engineers are such profane men.

On comparatively flat ground or rolling ground, the excavations and embankments may balance fairly well. On prairie, the grade will generally be above the ground a couple of feet, on account of drifting snow, the material being taken from the side ditches. On side hills, especially where it is steep, the profile will be delusion so far as quantities are concerned.

There is always the temptation with an engineer inexperienced in construction work, to locate the line so as to show a well balanced profile along steep side hills. The practice of promoting the transitman to chief of party as the next logical step in advance, regardless of his possible lack of knowledge of construction, generally results in a location which though looking well on paper, cannot be built except at a cost far beyond the probable estimate.

The slopes of the embankments may run out into a river; a creek may enter a river at the crossing so close to centre line that the creek will have to be diverted, possibly at great cost. Two creeks may converge into one just at centre line, so that a culvert built will project some distance up one creek (if embankment be high). This will necessitate the removal of the ridge between in order to divert the second creek. The location may be through a swamp where no suitable material for filling can be secured for miles, or where the line cannot be drained except by building ditches sometimes great distances, and where by a change of line and grade all this would not be necessary.

In low lying sections of country the principal thing to be considered is the drainage of the roadbed and the removal of the water from the right-of-way as quickly as possible. This question of drainage is too often overlooked in the location of a railroad.

The locating engineer should carefully estimate the sizes of culverts and openings required, and not leave this to the transitman or topographer, as is often the case. The contractor may give a

price for culverts say of 10 feet span at several openings, and refuse to go ahead on the work, and with good reason, when he finds the construction engineer has reduced these to say 4 feet span. It may not be worth the cost of bringing in his plant. In all fairness the engineer cannot hold him at the same price for say, hundreds of yards of concrete, when he had figured on thousands.

So important has the location of the line become, both as to initial cost and operating, that some roads, notably the Transcontinental (G. T. P. Ry.), have three locations, first, revised and final, made under three different engineers. That it pays to run a revised location under a different engineer has I think been proven, and the extra cost of survey has been more than paid for in every case. The value of the third or final location is doubtful in some sections anyway, and not worth the cost in others, providing the first two have been made under competent men.

Upon the profile should be noted the estimate to sub-grade for each mile as common excavation, loose rock, solid rock, borrow, overhaul, masonry, timber, rip-rap, bridges, and in fact everything to get a close estimate. To the estimated quantities ten or fifteen per cent. should be added, which should give a closer approximation to the correct quantities. At summits or depressions where the grades change, it is important that these changes be made by means of a vertical curve of such length as will allow the longest train to pass from one grade to the other without the cars piling up against each other. With the present equipment, this rate of change should not be greater than one-tenth of a foot per station in depressions and three-tenths of a foot per station on summits.

The use of "momentum" grades is not to be recommended in this country except under very exceptional conditions. The climatic conditions combined with snow may reduce the speed at the bottom of a grade to such an extent that the train will be "stalled" before reaching the top.

The three factors to be considered in comparing two lines (outside of commercial possibilities) are distance, rise and fall, and cur-

vature. Where distance is less than two miles, or so short as not to affect train or track wages, the justifiable expenditure per mile in saving of distance for one daily train per annum is $2,600 at present rate of interest. Where distance affects train wages, but not so great as to affect the number of stations or sidings (from 2 to 5 miles), the justifiable expenditure is $4,500. Where distance is so great as to affect the number of stations and sidings required (from 5 to 75 miles), the justifiable expenditure is $5,300.

With regard to rise and fall, the justifiable expenditure for one foot per daily train per annum will be $3; up to rise or fall of thirty feet $12 where grades require steam to be shut off, but not the application of brakes in descending. Where rise or fall over thirty feet on grades is less than 0.6 per cent. grade, and between thirty and one hundred feet on 0.6 per cent. grade, $22. This is assuming a maximum freight train speed of 30 miles per hour and the minimum of 10 miles per hour.

The elimination of one degree of curvature (central angle) will save 16 cents per daily train per annum.

Level crossings of other railways are always to be avoided on account of the cost of maintenance, and would justify an expenditure of $40,000. It is very doubtful if the Railway Commission would allow a level crossing in this country now. The above amounts are not to sub-grade only, but include ballast, ties, rails, etc.

In conclusion, I desire to say that the preceding notes, with the exception of train costs, will apply to electric as well as to steam railroads, although this paper was written with reference principally to steam roads.

PRODUCER GAS FOR POWER.

S. L. Fear, '06.

RIVALLED ONLY BY WATER POWER UNDER THE MOST FAVORABLE CONDITIONS.

The necessity for cheap power to the manufacturer, in these days of such keen competition, when he must get as large returns as possible from every cent expended, is one of the engineering problems of the twentieth century.

Necessity is surely the mother of invention, and with the necessity has come the invention. During the past few years the manufacturer has turned with interest and profit from the steam boiler and engine, with their numerous auxiliaries and low efficiency, to the gas producer and gas engine, since in these he finds a more compact and simpler plant, having a higher efficiency. He also finds his expense bill a great deal smaller at the end of the year.

The introduction of the suction gas producer came with the demand for a small compact gas producing plant to be used in connection with the gas engine. This demand was first realized and brought into practical application by the Germans and French about twenty-five years ago, but was rapidly followed up by the English and Americans. To-day, because of the efforts of these engineers, the suction producer gas plant is finding favor with the layman, the engineer, and the manufacturer, as the best means of obtaining maximum energy from cheap fuel.

Investigating the efficiency of the two classes of plants, both using coal and water as their sources of energy, we will find that the efficiency in the best regulated steam boilers and engines rarely

exceeds 14 per cent., and this efficiency depends not only on the type and size of the engine, but to a large extent on the auxiliaries, such as condensers, pumps, separators and economizers, without the use of which the efficiency often falls to 6 and even 3 per cent., which are common figures for non-condensing plants. If in place of the boiler we put a gas producer, and in place of the steam engine and auxiliaries we put a gas engine, an efficiency of 20 per cent. is commonly attained, even in small plants, and the tendency in larger powers and later developments is toward higher efficiencies yet, 24 having been obtained. Table I. gives an average of efficiencies of steam plants using the different types of engines, the coal used being assumed to have a heating power of 13,000 B.T.U. per pound. Table II. gives the efficiencies of the different gas engines connected to gas producers, from actual tests.

TABLE I.

Type	Pounds of Coal per B.H.P.	Thermal Efficiency (%)
Simple non-condensing—		
Throttling	6	3.26
Automatic	4½	4.35
Corliss	3½	5.6
Compound non-condensing—		
Corliss	3	6.55
Compound condensing—		
Corliss	2¼	8.75
Steam turbine condensing	1¾	11.25
Triple condensing Corliss	1⅓	14.75

TABLE II.

B.H.P.	Type	Fuel.	B.T.U. Fuel, per pound	Fuel in lbs. per B.H.P.	Thermal Efficiency (%)
20	Single cylinder,	anthracite	15,138	0.797	21.25
90	Single cylinder,	coke	12,411	0.910	22.5
250	Double acting,	anthracite	14,600	0.744	23.3
300	Two-cylinder,	anthracite	11,370	0.975	24.0

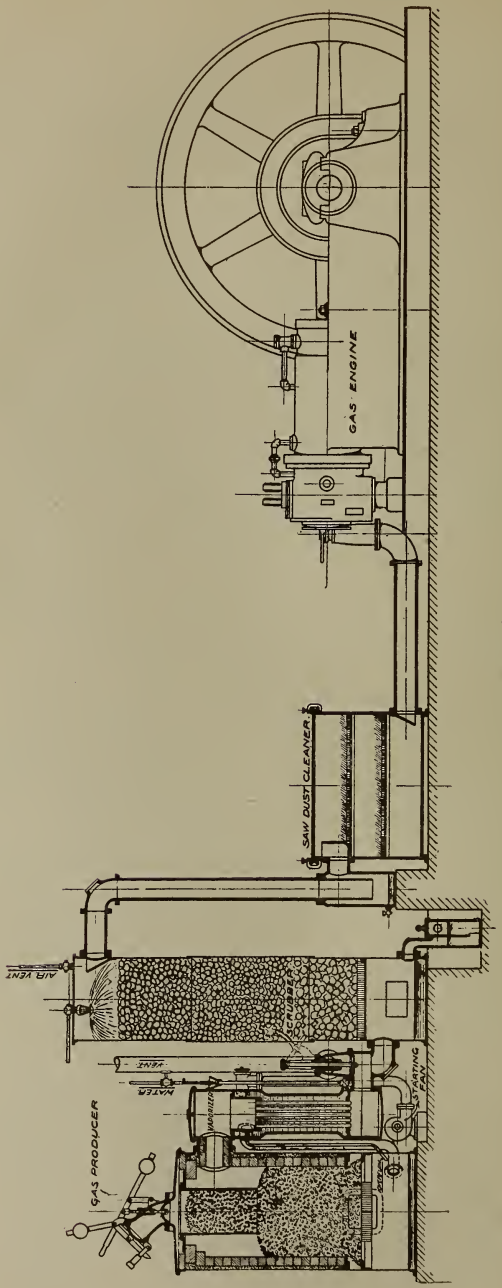


FIG. 1.

But why such high efficiencies? Well, let us look into the construction of a suction gas plant, and then we may be able to compare it with the steam plant, which is now so thoroughly understood. The main parts to the producer plant are generator, vaporizer, scrubber and equalizing tank. We shall take these up in order.

The Generator.—Figure 1 shows a cross-sectional view of an entire plant (Koerting). To the left is seen the generator. As will be seen, it is cylindrical in shape. The shell is made of steel plate to allow for expansion and contraction that takes place in operation, which contraction and expansion would soon destroy cast iron. Here the base is, also, made of steel plate, but is preferably made of cast iron, which is better suited to resist corrosion. Inside the steel shell, supported by the base, is a lining of brick. These bricks are quite often made of fire clay, but when made of silica will last longer. In a plant of 100 H.P. these bricks should not be less than 8 inches deep. Between the walls and the brick lining, ashes are usually placed to prevent loss by radiation. The usual style of fire grate as used in steam practice is placed in the base to support the coal. The grates are supported by the base, and are so arranged that they may be shaken by a lever outside the base. Doors are provided in the base and lower part of the generator proper, also poke-holes in the top, for the purpose of breaking clinkers in the fire and removing clinker from the bricks. A water seal is formed at the bottom by keeping water in the base up to a constant level. The top is usually flat, except for the coal-feeding apparatus, which is of several different shapes. The idea of all types is to feed the fuel to the generator, and not allow air to enter while feeding. For this purpose there are two joints, with a chamber between, which joints may be opened or closed, one independently of the other. The fuel is fed through the first opening into the chamber, the second opening being closed. The first is then closed and the second opened and the fuel drops into the generator without its being opened to the atmosphere. The air and steam, for combustion of the fuel and the formation of the gas, are brought to the grate through the base by a pipe from the vaporizer.

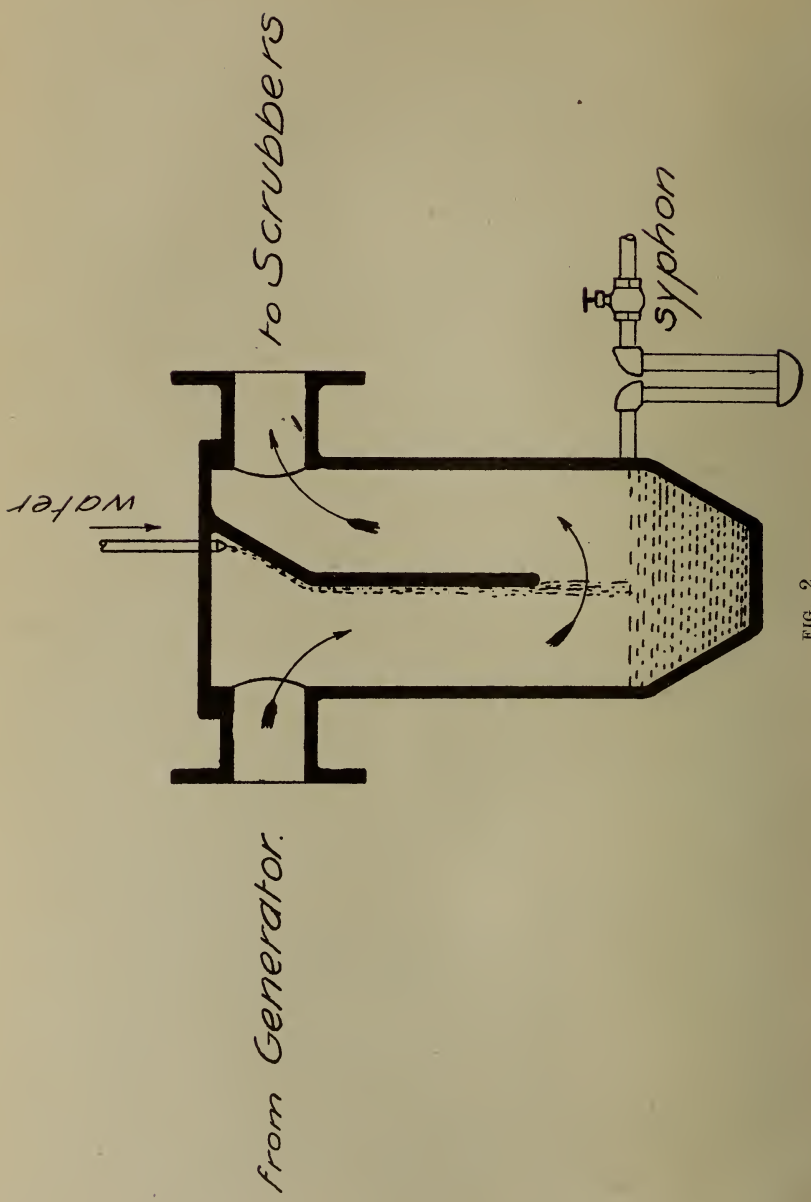


FIG. 2.

The gas at a high temperature is drawn from the generator into the vaporizer. The vaporizer serves a two-fold purpose—to cool the fresh hot gases and to supply steam for the formation of the gas. In some cases the vaporizer is placed at the top of the generator. Where the maker wishes economy by keeping as much heat as possible in the generator, and consequently less heat will be abstracted from the coal for combustion, the vaporizer is placed outside the generator in the shape of a small tubular boiler. The gases pass down through the tubes and give up to the water surrounding them a great deal of their heat, thereby changing the water into steam. Some makers have used a vaporizer in the top of the generator and a superheater outside. Why not use the generator outside and a separate superheater, which would be heated from the exhaust gases from the engine? An opening in one side of the vaporizer is arranged for the admission of the air from the other side, a pipe carries the air and steam to the generator. The level of the water is kept constant by a syphon.

The gas then passes into the scrubbers through the valves shown, which valve or valves are so arranged that the generator may either be connected with the scrubbers or the atmosphere. For this purpose two independent valves may be used, or a valve with a water seal, as shown in Figure 2. This seal is formed by closing the valve in the syphon, thus causing the water to rise in the chamber and stop the passage of gas to the scrubbers.

The scrubbers are tall cylindrical chambers. Their purpose is to clean and cool the gas. They are fitted with either wooden slats crossed and staggered or with coke or charcoal. The coke or charcoal is graded—coarse where the gas enters; fine where it leaves. But whatever is used, water is continually sprayed over the top layers and passes down through the wood or coke, cooling the gas and cleansing it by absorbing the dust. Quite often there is a dry cleaner placed either at the top or at the side of the wet scrubber. The dry cleaner is filled with sawdust, excelsior and shavings, which absorb the moisture from the gas. At the bottom the water which drips from the filtering or cleansing material is allowed to collect and kept at a constant level by a syphon, thus forming a water seal.

Since the production of the gas depends on the suction of the engine, and since this suction is not uniform, especially in a single-cylinder four-cycle engine, an equalizing tank is placed between the scrubber and the engine. This tank is just a chamber of several times the volume of the engine cylinder, and because of this furnishes a good full cylinder of gas to the engine on the suction stroke, since, between suction strokes, the tank fills again because of the vacuum produced.

Let us consider the action that occurs in the plant from the time the coal is fed into the generator until the gas is used in the engine. Air and steam are drawn into the generator from the vaporizer and up through the incandescent fuel bed. When they enter the fuel bed carbon dioxide is formed.

$$C + O_2 = CO_2$$

The carbon of the fuel unites with the oxygen of the air. As the CO_2 passes up, an excess of carbon is added and the oxygen having been used up the carbon dioxide becomes carbon monoxide,

$$CO_2 + C = 2\,CO.$$

But since air and steam were both added there is another reaction. The steam has served a two-fold purpose. First, it reduces the temperature of the fuel bed, and thereby keeps clinkers from forming; secondly, it furnishes oxygen without the presence of nitrogen. Then since the steam breaks up into its component parts hydrogen and oxygen, it enriches the gas by the addition of the hydrogen, and by supplying oxygen to the carbon of the fuel without the presence of the neutral nitrogen. The two reactions taking place are as follows:

$$H_2\,O + C = CO + H_2 \qquad (1)$$
$$2\,H_2\,O + C = CO_2 + 2\,H_2 \qquad (2)$$

The first is effected by high temperatures; the second by the low temperatures of the fuel bed.

In operating, a fire is kindled upon the grate and the fuel bed is built up in the usual manner, while the necessary air is supplied by a hand or belt-driven fan. The products of combustion escape beyond the vaporizer through a suitably arranged waste pipe. As soon as good gas is produced, as shown at a test cock, the scrubber and purifier are brought into the gas circuit and the whole apparatus filled with gas. When good gas appears at the engine

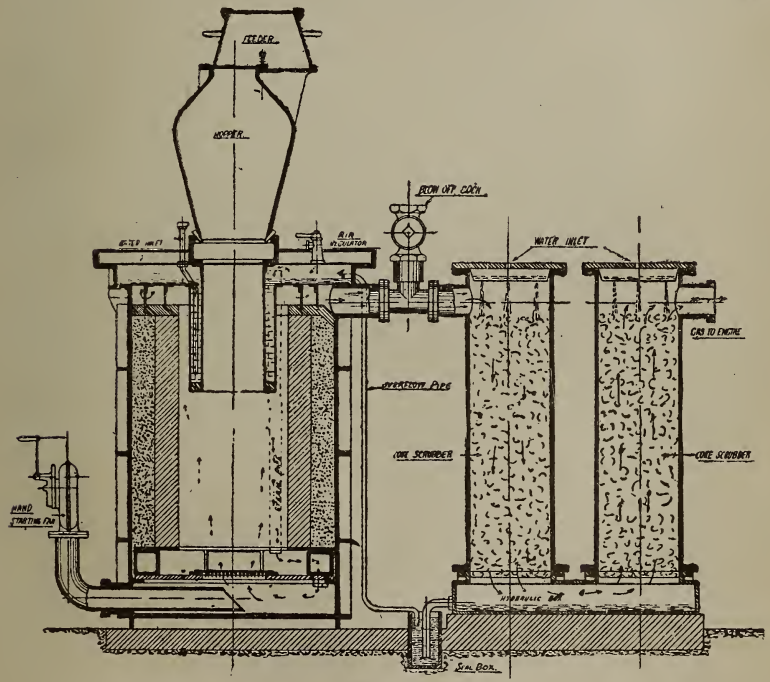


FIG. 3.

test cock, the engine is put in operation and the air fan stopped, its function being performed thereafter by the engine.

A comparison of the cost of operating between steam and gas may be made from Tables III. and IV., which are taken from two English plants of the same capacity, under the same management, having the same capital cost, but separated by about one mile. The first takes the lighting load; the second the power load.

Table III.

GUERNSEY STEAM AND GAS-DRIVEN ELECTRIC STATION.
COST OF WORKING, 1905.

	Steam Plant. Lighting Load. Per Unit Generated.	Gas Plant. Power Load. Per Unit Generated.
Coal, including steam pumps, air pump, forced draught at steam station	.436	.200
Oil, waste, water, stores	.037	.042
Wages	.214	.133
Average hours of attendance to run plant when necessary, per day	18	13
Repairs — Buildings, machinery, transformers, main accumulators	.250	.123
Total works costs	.937	.498
Units generated	500.43	718.858
Average per cent. of full load at which engines were loaded during the time of running	68½%	86¼%
Coal used per unit generated	4.97 lbs.	2.21 lbs.
Price of coal in bunkers—Washed anthracite peas used at each station	16s. 2d.	15s. 6d.

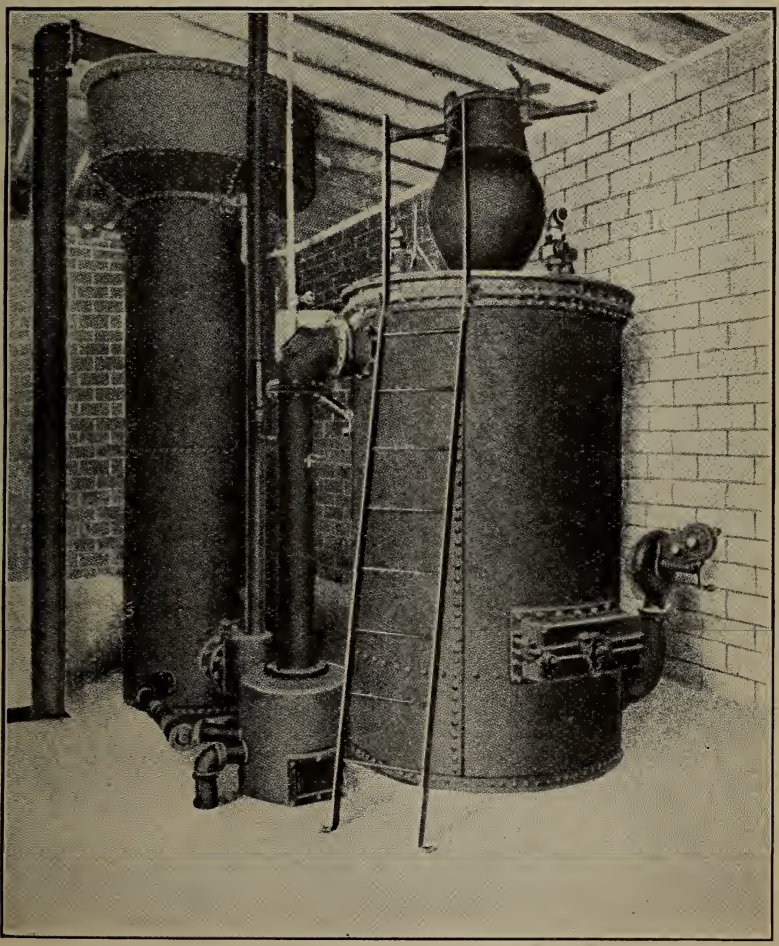


FIG. 4.

Table IV.

GUERNSEY STEAM AND GAS-DRIVEN ELECTRIC STATION.
COST OF WORKING, JANUARY TO MARCH, 1906.

	Steam Plant. Lighting Load. Per Unit Generated.	Gas Plant. Power Load. Per Unit Generated.
Coal, as in Table III.	.391	.151
Oil, etc., " "	.027	.046
Wages, " "	.209	.136
Repairs, " "	.207	.176
Total works costs	.834	.509
Units generated	164,323	162,438
Price of coal in bunkers	16s. 2d.	15s. 6d.

A cost of operating a gas plant for a month may be had from Table V.

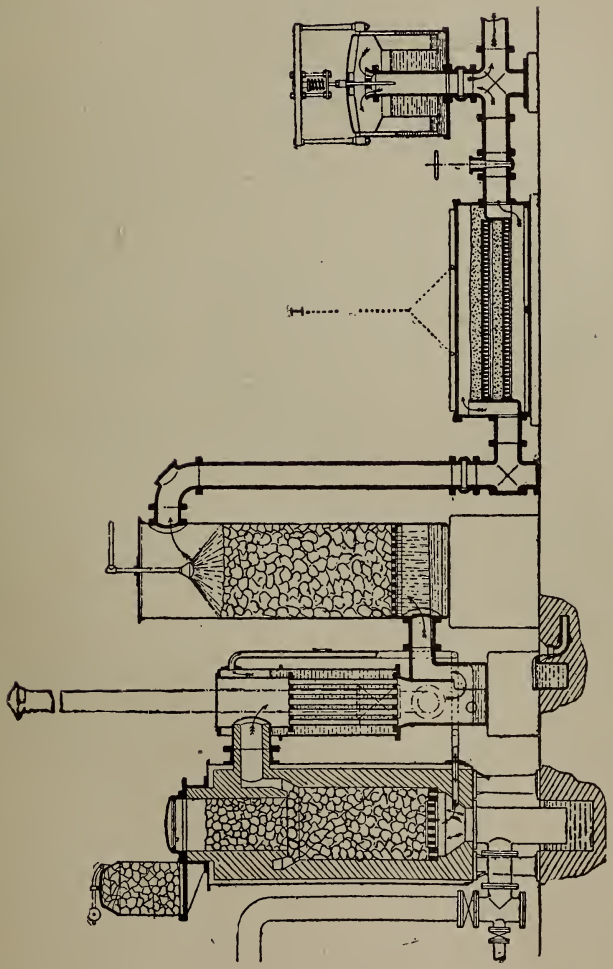


FIG. 5.

Table V.

COST OF WORKING BROXBURN ELECTRIC POWER STATION FOR OCTOBER, 1906.

Twenty-nine Working Days.

Total fuel consumed	6 tons 13 cwt.
Total units generated	6917.
Duration of run per day	7½ hours.
Units generated per day	231.
Consumption of fuel per hour	69 lbs.
Units generated per hour	33.
Consumption of fuel per B.H.P. per hour	1·25 lbs.
Cost of fuel per B.H.P. per hour	·08d.
Consumption of fuel per unit	2·09 lbs.
Cost of fuel per unit	138d.
Consumption of oil	10 gallons.
Cost of oil per gallon	2s. 3d.
Cost of 20 B.H.P.	1·6d.
Cost of fuel in bunker	12s. per ton.

From this table one may see that the stand-by losses have been included. (By stand-by losses in the suction gas plant we mean the amount of coal consumed to keep the fire alight from the time the engine is shut down to the time of starting again.) In Tables VI. and VII. a comparison of these stand-by losses may be made between steam plants and gas plants.

Table VI.

CONSUMPTION OF FUEL IN STEAM BOILERS IN STANDBY HOURS.

	Type of Boiler	Max. H.P. of Boiler	Coal consumed per standing hour	Authority
1.	Various	100	14·0 lbs.	Mr. Deely, Loco.-Supt., Midland Railway
2.	Lancashire ...	450	*37·5 "	Mr. Henry Lea
3.	Babcock & Wilcox	210	67·0 "	Col. R. E. B. Crompton
4.	" "	210	67·0 "	" " "
5.	" "	500	180·0 "	Mr. H. Collins Bishop
6.	" "	500	112·0 "	" " "
7.	Niclaussé ...	400	50·0 "	Messrs. Willans & Robinson
8.	Lancashire ...	400	44·7 "	Mr. F. A. Wilkinson
		Average	71·5 lbs.	

* Exclusive of raising the steam pressure from 90 to 120 lbs.

Table VII.

CONSUMPTION OF FUEL IN GAS PLANT IN STANDBY HOURS

	Locality	Max. H.P. of Producer	Coal consumed per standing hour	Authority
1.	Openshaw ...	250	5·1 lbs.	Messrs. Crossley Bros., Ltd.
2.	" ...	250	3·9 "	" " "
3.	Leicester ...	100	2·1 "	Mr. Deeley (Midland Rail.)
4.	Smallheath ...	250	4·5 "	Mr. Henry Lea
5.	Limerick ...	225	3·8 "	Mr. J. Enright
6.	Walthamstow ...	375	1·8 "	Mr. F. A. Wilkinson
		Average,	3·5 lbs.	

The cause of this great difference may be explained by the fact that the gas plant is smaller per horse power than the steam. The radiating surface is not so large and steam has not to be raised to a high pressure.

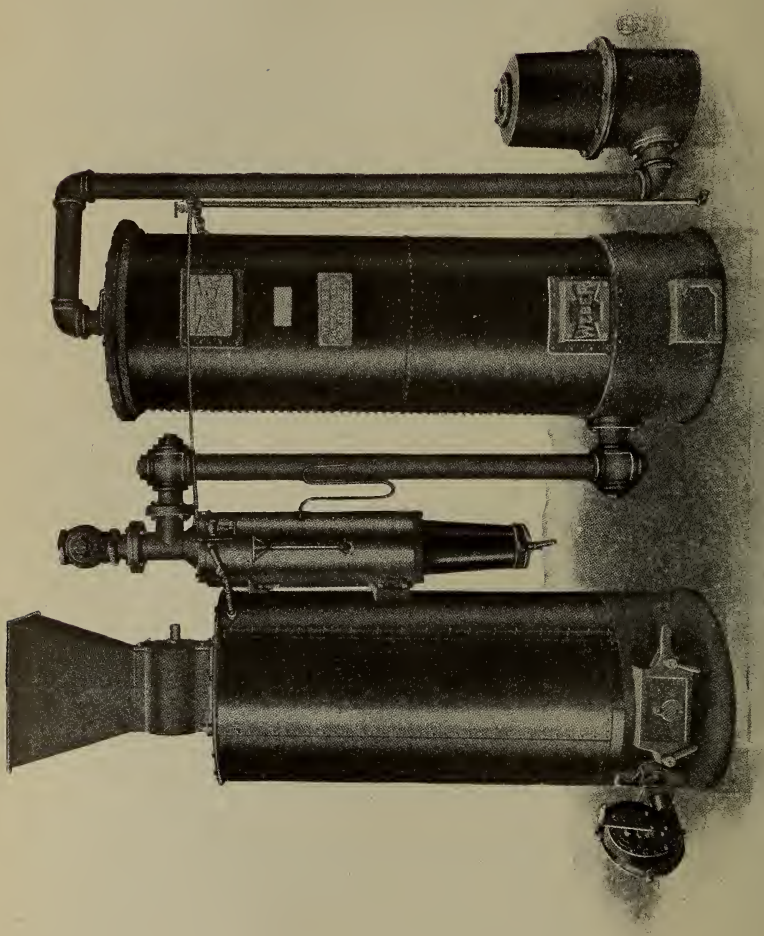


FIG. 6.

Although English and foreign practice may have been ahead of the American, yet the following Table, No. VIII., will show that the American is following very rapidly on the heels of the fathers of the suction gas plant.

TABLE VIII.

The gas producer was built by the Cone Gas Machine Co., Detroit, Mich. It was rated at 25 H.P. The engine was a Bruce-Meriam-Abbot gas engine, vertical, 8.5″ x 10″ cylinders, and was belted to a 17.5 K.W. 110-volt Triumph generator. In the test a bituminous nut coal from Springfield, Ill., costing $1.75 per ton f.o.b. Chicago, was used, with results as follows:

Pounds of coal per hour, 13.12.
K.W.'s per hour by wattmeter, 14,616.
K.W.'s per hour by volt and ammeter, 13,050.
Electric horse power per hour, 17.4.
Efficiency of dynamo and belt assumed, 80%.
Brake horse power per hour, 21.7.
Pounds of coal per B.H.P. hour, 0.6.

The use of the suction gas plant in marine work, and especially in the navy, is another big field only recently opened. The chief advantages are as follows:

1. A saving in weight of machinery and boilers, which can be applied to other parts of the ship.

2. A saving of labor since the coal can be mechanically dropped into the producer, whereas it must otherwise be shovelled into the furnace of the boiler.

3. The pressure in a producer is below atmospheric pressure, while in a boiler it is a great deal above. The puncturing of a producer by a shell will thus not be nearly as serious a matter as the puncturing a boiler. One producer can be easily cut out in an emer-

gency and those remaining are capable of taking an overload better than a number of steam boilers.

4. A ship having producers cannot be discovered by her smoke —there is none.

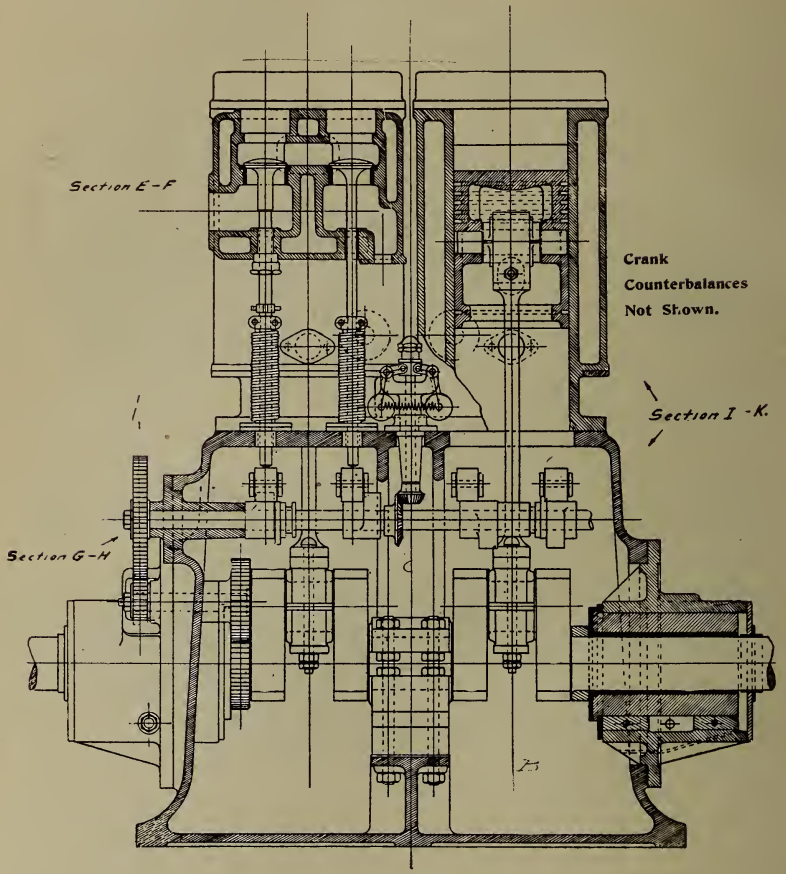


FIG. 7.

The source of energy may be important, but we must have with the source the means of turning the energy into mechanical work. The gas producer as the source has the gas engine as its transformer of energy.

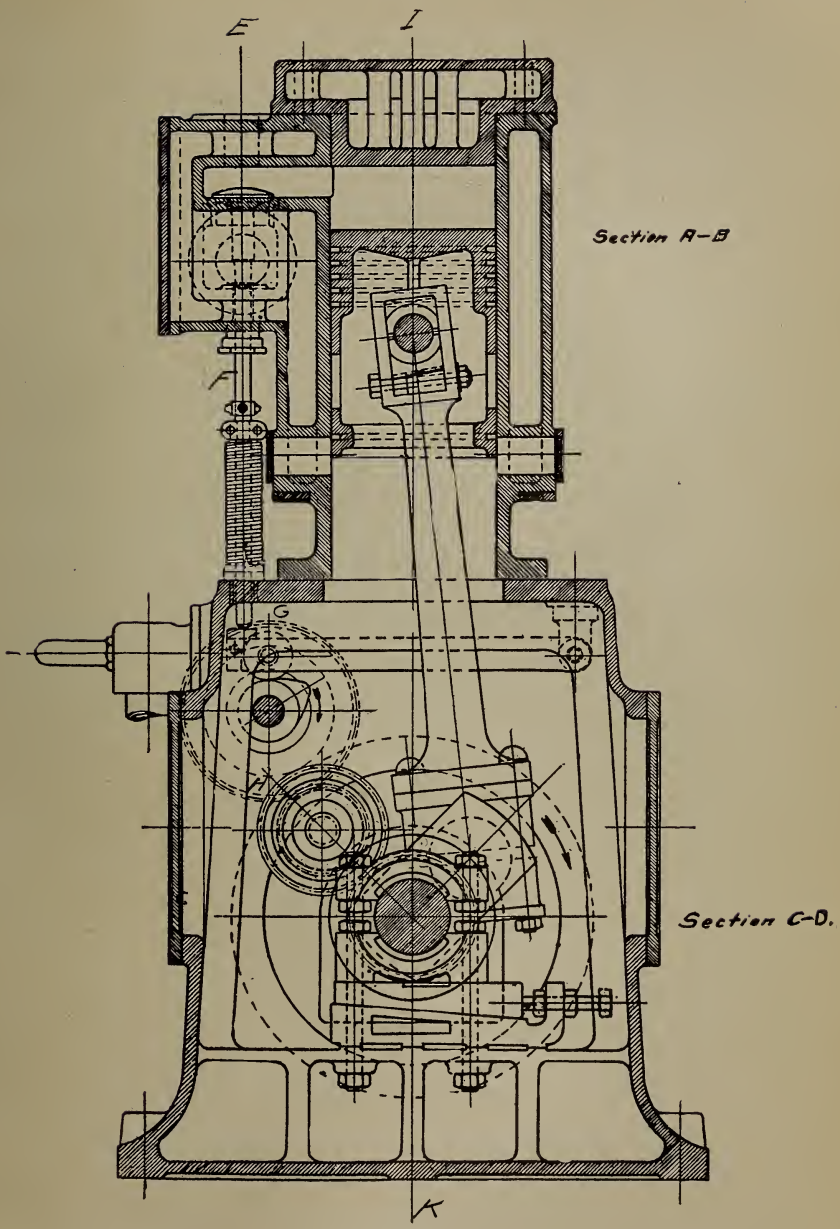


FIG. 8.

It is impossible in this paper to go into the design of gas engines, but in passing it may be said that the compression for producer gas engines average 160 pounds, the exhaust valve is water cooled, and forced lubrication is employed. Figs. 7 and 8 illustrate an American engine in which simplicity, strength and durability have been combined to make one of the most efficient engines on the market. This engine is manufactured by the Weber Gas and Gasoline Engine Co. of Kansas City, Mo., who also manufacture the producer shown in Figure 6.

Figure 3 is a section of the Crossley Producer.
Figure 4 is a view of the Wile Producer.
Figure 5 is a view of the Pintch Producer.

The idea of this paper has been to give a short description of this new method of obtaining energy from coal which is now attracting so much attention. It is hoped that the information will be of some benefit to you who read, but whether manufacturers or power users, do not allow this information to lead you manufacturers to give to the public a guarantee which you are not sure you can back up; or you power-users to demand of the manufacturer things utterly unreasonable and impossible.

THE ELECTRO-METALLURGY OF IRON AND STEEL.

S. Dushman, B.A.

It is not so long ago that the only means used for attaining high temperatures were limited to the furnaces working with blast or the oxy-hydrogen flame. With the development of electrical generating machinery and the utilization of water power for lighting and power purposes, it became apparent that herein lay another resource for obtaining great heat. To Sir William Siemens, the great iron metallurgist of the 19th century, belongs the credit of having been one of the first to see the advantages of electro-thermic processes. But it is only recently that the greatest advance in this work has taken place.

Electricity may be used to produce heat by the following methods:—

1st. The use of the electric arc. The arc light is familiar to everybody as a source of very intense light; but it may also be used as a source of heat. The temperature obtainable by this means has been estimated to be about 3,500°C, and a number of electric furnaces have been invented utilizing this source of heat.

2nd. The heating effect due to the passage of an electric current through a conductor. An example of this is the ordinary incandescent light. The electric current passing through the carbon filament of the lamp causes it to be heated to incandescence. The amount of heat generated in a conductor depends upon its resistance and the amount of current that is passing. In fact the higher the resistance and the greater the current the more heat that is produced. The furnaces built on this principle are of the resistance type.

3rd. By the inductive effect of an alternating current passing in one circuit on a neighboring circuit. This is really another variation of the principle used in a previous type. The induction furnace has as yet a very limited application.

The advantages of these various methods of generating heat are very evident. Firstly, the temperatures attainable are much higher than by the other methods in previous use; thus many reactions which are impossible at relatively lower temperatures can be made possible in the electric furnace, and many products which were unknown before the last few years are now produced in large quantities. Secondly, the electrical energy can be utilized as heat much more efficiently than that from coal, because it is applied to the materials to be heated directly and not through the intermediary of refractory walls. Thirdly, the electric furnace is very compact and much more easily controlled as to temperature and character of product than the ordinary furnace.

The electric furnace industry has been a great boon to the development of metallurgy and applied chemistry. From an appliance that was used merely for the fusion of refractory substances and the attainment of very high temperatures, the electric furnace has become a factor in the processes for which coal or gas has hitherto been used; and the older methods are competing against the newer and more aggressive industry.

In the following paper, I intend to deal with the electric furnace as applied to the metallurgy of iron and steel. The whole subject naturally resolves itself into the solution of the following chief problems:

(1) Processes for producing pig iron and steel from ores.

(2) Processes for producing steel and wrought iron from pig produced either in the electro-thermic or blast furnace process.

(3) Processes for the production of the very infusible alloys of iron with silicon, manganese and chromium.

THE PRODUCTION OF PIG IRON FROM ORES.

As Borchers has remarked in his book: "It must be remembered at the outset that of all metallurgical industries, the blast furnace industry with its process of treating the waste gases produced, has been the most thoroughly worked out. There is no metallurgical furnace which has yet attained so high an energy efficiency. Stress must be laid upon this, in order that the difficulties may be appreciated which the electric furnace must encounter in order to compete with the existing blast furnace."

However, there are many localities in which the older processes are not practicable owing to cost of fuel, one of these localities being northern Ontario, and in order to find out if electro-thermic processes could not be useful there, a commission was appointed by the Canadian Government in 1903, "to proceed to Europe for the purpose of investigating and reporting upon the different electro-thermic processes employed in the smelting of iron ores, and the making of the different classes of steel, now in operation, or in process of development, in Italy, France and Sweden." The report of this commission issued in 1904 forms an almost complete summary of all the electrical processes in use for iron and steel, and I have availed myself to a large extent of the information therein contained.

Before we consider, however, the various methods in use for the electrical reduction of iron ores, it may be worth while to briefly consider the operations that are performed in a blast furnace. In the latter the charge consists of iron ore, coke and a flux consisting either of lime or sand or a mixture of both. The coke contains nearly pure carbon, which combines with the oxygen contained in the iron ore, and thus sets metallic iron free. This iron is then melted by the aid of a heat derived from an extra amount of coke. Thus the latter performs in this case two quite distinct and special functions, one of chemical reduction, and the other in fusing the reduced metal. For instance, in a blast furnace there is usually consumed about one ton of coke per ton of pig iron; the theoretical quantity needed for the reduction is only about one-third that

amount, and the rest of the coke is simply used to supply the heat necessary to raise the materials of the charge to the temperature at which the chemical reaction will take place and also to fuse the reduction product. The electrical energy can evidently be used only for the purpose of replacing the last named portion of the coke and not that part which is used for chemical reduction.

By calculation of the thermal energy required for these processes, it has been shown that adding the proper quantity of coke for the chemical reaction alone and utilizing electrical energy to provide the source of heat, it requires 3.8 electrical H.P. hours per kg. of iron, or approximately one-third of a H.P. year for one ton of iron. As the difference between the coke actually consumed in a blast furnace and that theoretically necessary for reduction is about 1,200 lbs. of coke per ton of iron, this can be interpreted thus: Assuming that labor and other charges are the same in the two methods, the electrical will be the cheaper if the cost of one-third of an electrical H.P. year is less than that of 1,200 lbs. of coke. With the latter at $6.00 per ton this limits the cost of electrical power to $10.80 per H.P. year. Thus wherever power costs less than that, the electrical method is the cheaper. Of course, as the price of coke decreases so must that of power, in order to make the processes comparative; and wherever the price of coke is high and power is plentiful the electrical method offers the greatest advantages.

The three important methods used for the extraction of iron from its ores are those of Stassano, Keller and Heroult.

(1) *The Stassano Process.*—The furnace used is of the arc type, and M. Stassano, the inventor, deserves great credit for the perseverance with which he attacked the problem of replacing blast furnaces by an electrical method. The form finally adopted by him is shown in Fig 1. The charge is calculated accurately beforehand from an analysis of the ore, coke and flux used. This is then moulded in the form of briquettes and subjected to the radiation of heat from an electric arc situated above the charge to be heated.

The furnace consists of a cylindrical outward casing of iron surmounted by a conical roof. It is lined with magnesite brick and rotates about an axis, which is slightly inclined to the vertical. A three-phase alternating current of 400 amperes and 90 volts between

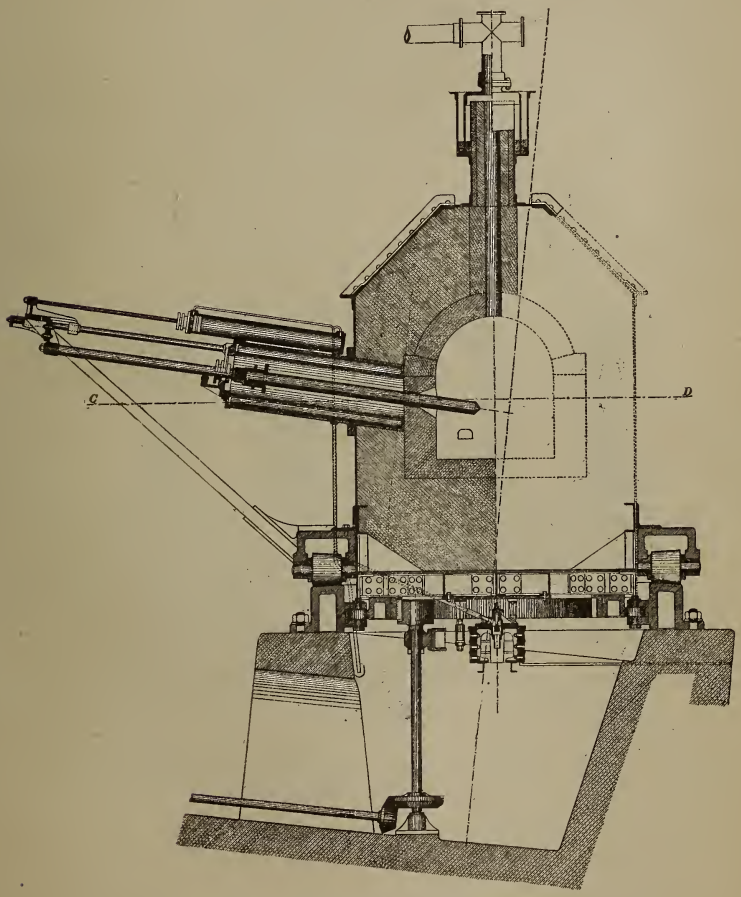


FIG. 1.—STASSANO FURNACE.

the phases is distributed to the three electrodes, which nearly meet in the centre of the interior of the furnace. Experiments performed in 1903 showed that the power used in producing iron by this process is about 0.27 electrical H.P. years per ton of iron.

(2) *The Keller Process.*—This furnace is illustrated in Fig. 2, and is the invention of M. Keller of Keller, Leleux and Co., of Livet, France. The charge is introduced between the carbon blocks of the base and ends of the electrodes, which latter are then in their low-

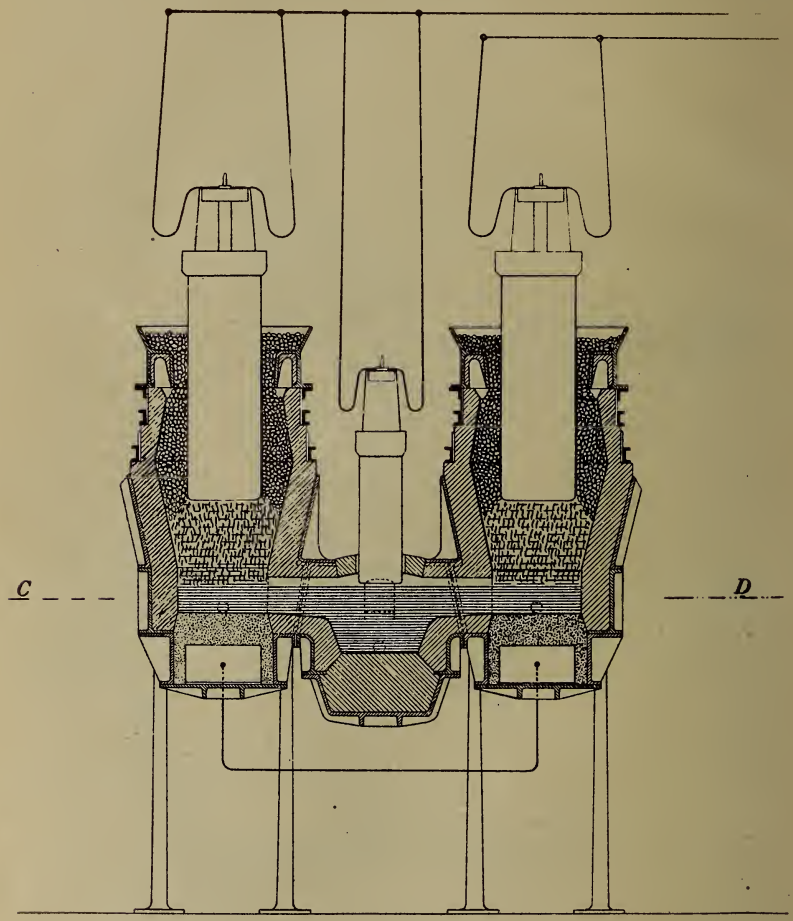


FIG. 2.—KELLER ELECTRIC HIGH FURNACE WITH A PLURALITY OF HEARTHS.

est position. The current passes from one electrode through the material to be reduced to the other carbon blocks, from thence outside of the furnace by means of the copper conductor to the other carbon block, and through the charge in the second shaft to the other

electrode. The current meeting in the two shafts with the resistance of the charge, the latter is heated; the reduced metal flowing along the canal conducts the electric current from one electrode internally to the other electrode. The exterior current diminishes as the amount of metal increases. The electrodes are now raised, the charging continued, until finally the electrodes occupy the normal position, and the shafts below the electrodes and the sides of the shaft are completely occupied by the charge. When the Canadian

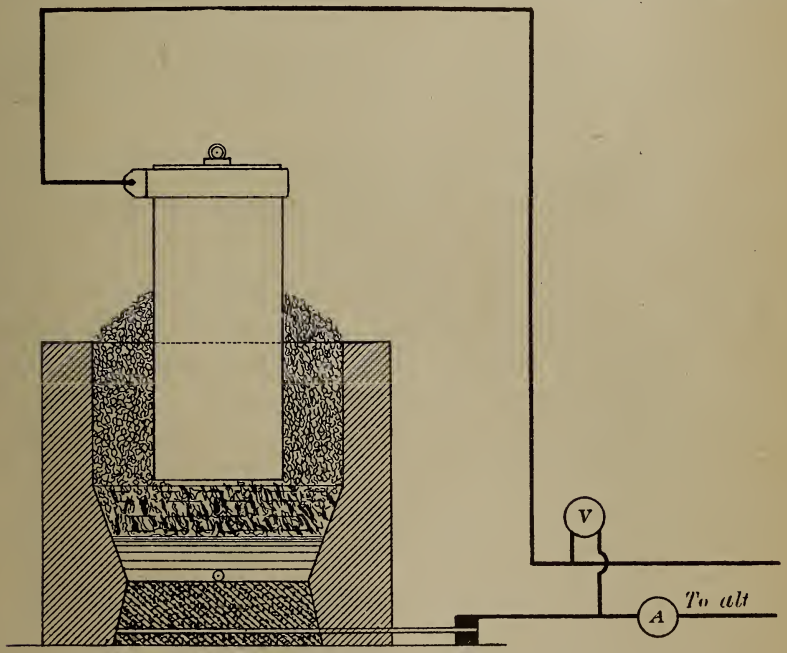


FIG. 3.—DIAGRAM SHOWING ELECTRICAL CONNECTIONS OF THE FURNACE EMPLOYED FOR MAKING PIG IRON AT LA PRAZ.

Commission visited the works of Keller, Leleux and Co. some experiments were performed by Keller on the reduction of hematite. The results of these experiments gave an average yield of one ton of pig iron per 0.35 electrical H.P. years; and the pig iron produced could be varied in composition as desired. Mr. Harbord, the metallurgist who accompanied the commissioners, estimates that the cost of iron by Keller's process is about $12.05 per ton.

(3) *The Heroult Process.*—The design of Heroult furnace as used by the Commission in an experiment at LaPraz, France, is shown in Fig. 3. In mode of operation and principle it resembled the Keller process.

Very recently, as is well known, some experiments on iron reduction were made by Dr. Haanel at Sault Ste. Marie. The furnace used was a design of Heroult and is shown in Fig. 4. The object of these experiments was to investigate the following points:

(1) "Can magnetite, which is our chief ore, and which is to some extent a conductor of electricity, be successfully and economically smelted by the electric process?

(2) "Can iron ores with comparatively high sulphur content, but not containing manganese, be made into pig iron of marketable composition?

(3) "The experiments made at Livet with charcoal as a reducing agent in substitution for coke having failed, could the process be so modified that charcoal, which can be cheaply made from mill refuse and other sources of wood supply useless for other purposes, could be substituted for coke? This is especially important since charcoal and peat-coke constitute home products, while coal coke for metallurgical processes required to be imported into the provinces of Ontario and Quebec."

The classes of ore treated were hematite, magnetite, pyrrhotite, and a titaniferous iron ore. As reducing agent was used either charcoal or peat in the form of briquettes. Alternating current of 5,000 amperes and 40 volts was used. The average consumption of power was 0.267 electrical H.P. years per ton of pig iron, and the charcoal used averaged 1,100 lbs. per ton of pig iron. As a blast furnace usually requires 2,000 lbs. of coke, the gain in this is 900 lbs. (assuming, of course, that 1,100 lbs. coke would be required in the electric process), and therefore the electrical power which amounted above to 0.267 electrical H.P. years must cost less than 900 lbs. of coke if the electrical furnace is to compete with the blast furnace.

With coke at $6.00 per ton, this makes the maximum cost of electrical power at $10.00 per H.P. year. In Table 1 I have given a tabulated summary of the experiments mentioned by Dr. Haanel in his preliminary report.

In the column under the head of "slag," I have given the composition of the latter in terms of the ratio between the percentages of silica and of bases present. Thus the basicity of the slag increases from experiment No. 1 to No. 7. In the next column to this I have given the ratios between the percentages of sulphur in the slag and the corresponding values in the metal. It will be noticed that as the basicity of the slag increases so does the sulphur in it; but experiments 5 and 6 form an apparent exception. This is however

Table No I

No	Ore			Iron				Slag $\frac{\text{acid}}{\text{base}}$	Distribution of S. $\frac{\text{Slag}}{\text{Metal}}$
	Source	P	S	C	Si	S	P		
1	Magnetite (Wilbur)	0.01	0.01	4.80	1.55	0.016	0.026	0.56	16
2	Hematite	0.044	0.002	4.55	0.95	0.018		0.55	31
3	Magnetite (Blairton)	0.016	0.06	3.70	3.50	0.042	0.034	0.54	48
4	Magnetite (Calabogie)	0.02	0.17	4.20	1.75	0.05	0.047	0.47	296
5	Magnetite (Calabogie)	0.42	0.45		1.52	0.015	0.51	0.424	88
6	Magnetite (Calabogie)	0.37	0.20	3.47	1.01	0.02	0.50	0.328	78.5
7	Pyrrhotite	0.016	1.56	3.0	4.9	0.007	0.05	0.214	800

explained because of the high phosphorus content in the iron in those two cases. These facts are of the same nature as have been observed in the ordinary blast furnace and Bessemer processes. A very basic slag helps to drive out sulphur from the metal, but high phosphorus content retards the elimination of sulphur; and furthermore, it has been claimed that a very high temperature prevents oxidation of the phosphorus and causes the iron to reduce the phosphates in the slag. It is probably due to the very same causes that the phosphorus in the ore was not eliminated in Dr. Haanel's experiments.

The experiment on pyrrhotite is very important. A blast furnace will not usually handle high sulphur ores, and requires therefore

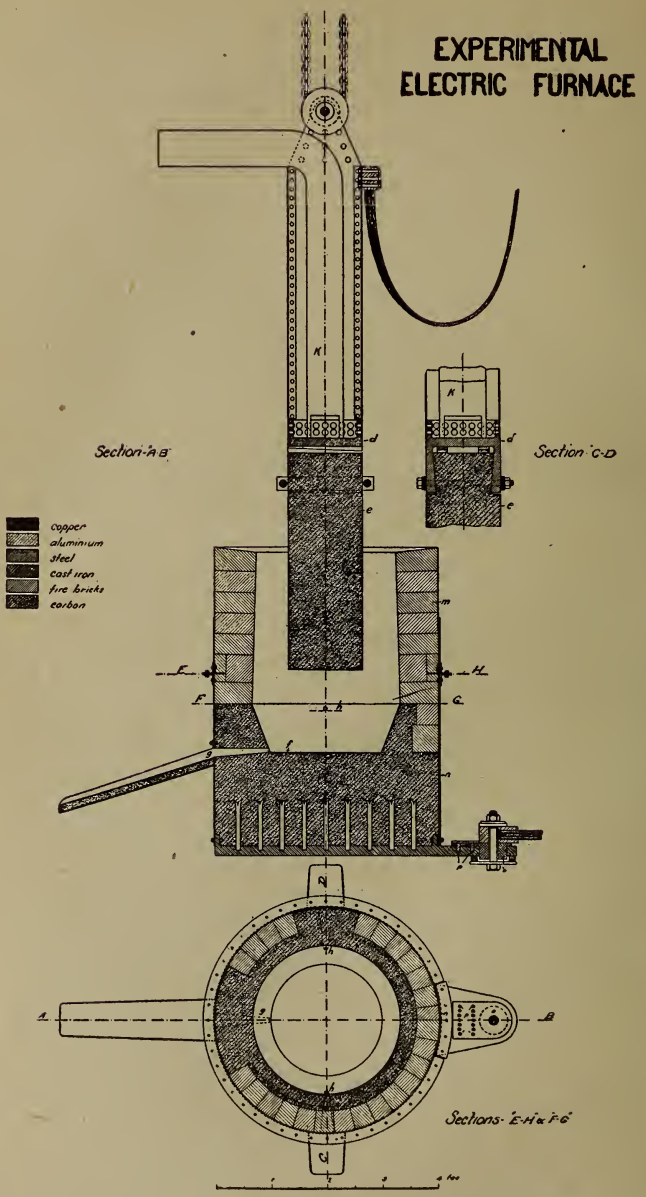


FIG. 4.—ELECTRIC FURNACE EMPLOYED BY DR. HAANEL AT SAULT STE. MARIE.

an ore which cannot be bought in Canada at a low figure. Dr. Haanel has stated that he understands the Algoma Steel Works paid $3.75 for the hematite ore which they use in their furnace. Pig iron equal in value and lower in sulphur contents can be made by the electric process from high sulphur ores which can be bought for $1.25.

The conclusions given by Dr. Haanel at the end of his report are as follows:—

(1) Magnetite can be as economically smelted by the electro-thermic process as hematite.

(2) Ores of high sulphur content not containing manganese can be made into pig iron containing only a few thousandths of a per cent. of sulphur.

(3) The silicon content can be varied as required for the class of pig to be produced.

(4) Charcoal which can be cheaply produced from mill refuse or wood which could not otherwise be utilized, can be substituted for coke as a reducing agent without being briquetted with the ore.

(5) A ferro-nickel pig can be produced practically free from sulphur, and of fine quality, from roasted nickeliferous pyrrhotite.

(6) The experiment made with a titaniferous ore containing 17.82 per cent. titanic acid, permits the conclusion that titaniferous ores up to perhaps 5 per cent. titanic acid can be successfully treated by the electric process.

In 1903 Keller delivered a paper before the Iron and Steel Institute on this subject, and made this statement: "It may be stated at once that the employment of electricity as a reducing agent is only practicable from an economic point of view, first when it is a question of manufacturing special qualities of iron from pure ore delivered at the works on favorable terms; secondly, when it is desired to foster an iron and steel industry in a country hitherto undeveloped in this respect, into which all the coal must be im-

ported, where iron ore of good quality abounds, and where natural resources of power are available in the immediate neighborhood of the ore deposits. The scale of production of an electric furnace is less than that of a blast furnace, and on this account the establishments equipped for electric working would be of less capacity and the working expenses proportionately higher. But the iron produced may be made much purer in the electric furnace. A further advantage consists in the higher temperature of working which the use of electricity permits, without, however, causing an excess of carbon in the material. It is also possible in consequence of the hot working to form slags of ultra-basic character."

The prospects of the electrical iron industry in Canada would therefore appear very bright. The provinces of Ontario and Quebec contain both iron ore and plenty of water power; as shown in the above experiment charcoal can be used as a reducing agent. The electrical processes would have therefore very many advantages over blast furnaces. It is to be hoped that our Government will see fit to promote this new industry and thus develop Canadian enterprise in one more direction.

METHODS OF PRODUCING STEEL FROM PIG IRON.

In the ordinary metallurgical processes pig iron is converted into steel by oxidizing the sulphur, phosphorus and silicon as well as some of the carbon. The process used for this varies according to the nature of the pig iron. In the electrical furnaces used for this object the oxidation is performed by adding ore and flux in sufficient quantity to oxidize part of the carbon and slag out the phosphorus and sulphur. The chief processes used are the following:

(1) The Kjellin process.

"At the Gysinge works, steel of superior quality is made by the smelting together of charcoal, pig, and scrap in an electrical furnace of the induction type." Fig. 5 illustrates a 225 H.P. furnace as used by Kjellin. The primary current is 3,000 volts and 50 to 90

amperes. The cost of producing steel by this method is about $1.45 per ton, the cost of power being estimated at $10.00 per H.P. year. The process is adapted for the production of high carbon steels and very little slag is produced. The product compares favorably with the best crucible steel made in Sheffield and the cost is much smaller. In the crucible process about 2½ to 3 tons of coke

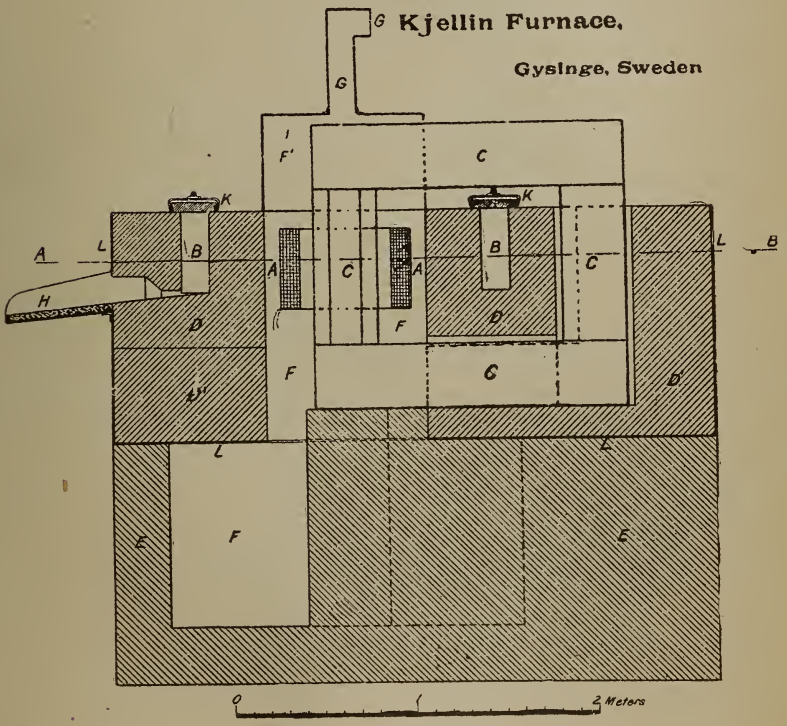


FIG. 5.—KJELLIN FURNACE.

is used per ton of steel, and even in the large gas-fired furnaces employed in Germany and America probably one ton of slack coal costing not less than $2.50 per ton is necessary.

The induction furnace has however many disadvantages due to its electrical construction which will prevent its capacity from being made much larger.

THE HEROULT PROCESS.

The furnace used is shown in Figs. 6 and 7. The current passes from one electrode through the narrow air gap left between the electrodes and the slag line into and through the slag to the molten metal, along it, through the slag and the second air gap to the other electrode. An alternating current of 4,000 amperes at 110

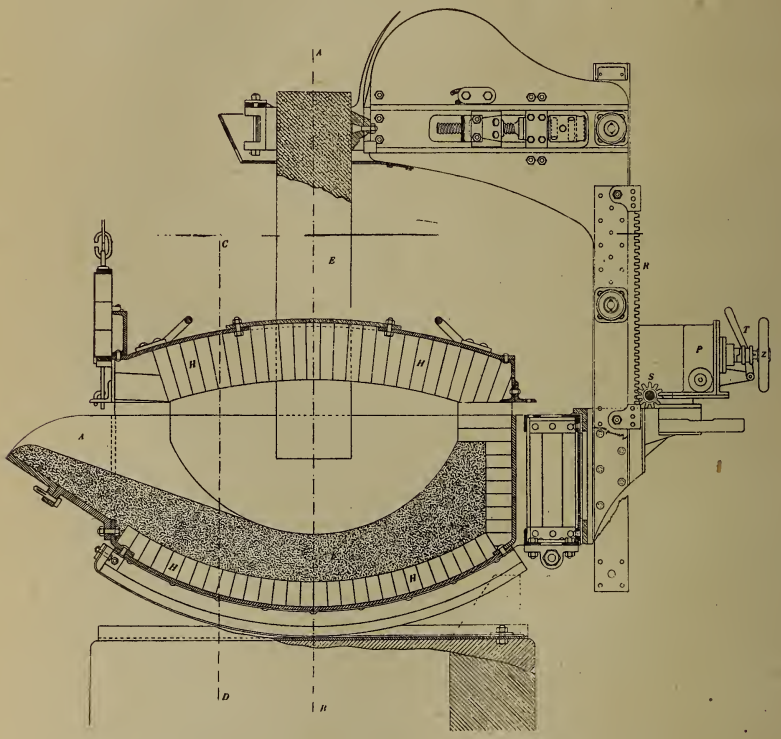


FIG. 6.—HEROULT STEEL FURNACE: TRANSVERSE SECTION.

volts is used. The scrap and iron ore, together with the flux used for the charge, are calculated beforehand, and then the slag is removed from time to time until steel of proper composition is obtained. To produce high carbon steel an alloy of iron and carbon called carburite is added to the molten bath. Thus this process has the advantage over that of Kjellin because it permits the puri-

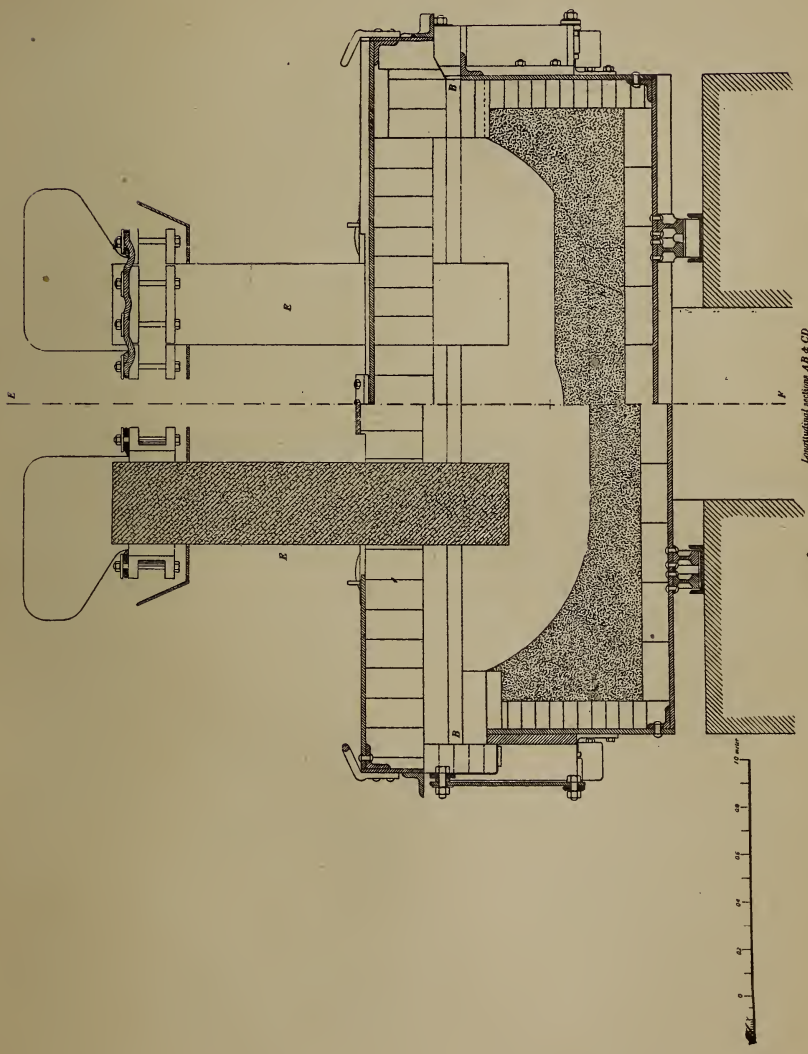


FIG. 7.—HEROULT STEEL FURNACE: LONGITUDINAL SECTION.

fication by renewed slags of the materials originally put into the furnace. The cost of making steel by this method is about $1.70 per ton. A gas fired Siemens furnace producing similar material would require about 1,200 lbs. slack coal at $5.00 per ton, *i.e.*, the cost of fuel would be about $3.00. Thus there is a balance in favor of the electrical method. There is a further advantage that owing to the high temperatures attainable a more basic slag can be used and thus completely remove phosphorus and sulphur. The only disadvantage is that at present the capacity of such a furnace can be increased to possibly 15 tons, but not much higher. It is of interest that on April 4th, 1906, a Heroult steel plant was started at Syracuse and is operating splendidly.

THE KELLER PROCESS.

The principle of this is really the same as that used in the Heroult furnace previously described. An interesting feature is a combination of pig iron and steel furnace which M. Keller would adopt. The latter is a simple crucible with two electrodes suspended in it. The molten pig is tapped directly into this refining furnace, where the phosphorus, sulphur and silicon are slagged out by a suitable flux. The electric power consumed in this method is even less than in the Heroult process. The power used in making one ton of mild steel is about 1-10 of a h.p. year, so that the cost is very small, and with power even as high as $30 per h.p. year, the cost would be smaller than in any metallurgical process. In recent articles published in The Electro-chemical Industry, it has been shown that the waste gases from blast furnaces contain a great deal of available energy for power. This could be utilized in gas engines at a cost of about $30 to $40 per h.p. year. It is therefore very probable that electric furnaces for producing steel will be a common accessory in the future to all blast furnaces. In fact the field for utilizing electric power in the production of steel is much more enticing commercially than the processes of making iron from the ore. It must not be forgotten that the works of Kel-

ler, Kjellin and Heroult are producing steel that is competing successfully against the best English crucible and Siemens products.

Electrical smelting is used almost exclusively for the production of the very infusible alloys of ferro-silicon, ferro-chrom, ferro-manganese, etc. These alloys have proven useful for the production of various special steels and the demand for them is increasing. The conclusions that can be drawn from the work done in this field so far seem to be that the electrical furnace is far superior to other existing processes for the production of special high grade steels and refining steel from scrap. There also seems to be a bright future for a large electric mixer to secure uniformity in the product of an entire works, as has been proposed by both Keller and Heroult.

There is still another direction in which the electric furnace may benefit the iron and steel industry. At present the foundry man who makes castings of cast iron usually leaves the steel castings for another firm that makes a specialty of these, but with the electric furnace he need not do this. At a nominal cost for power he could produce castings of steel from the smallest size up to probably 15 ton masses. Every machine shop might have a small electric furnace, in which could be melted the iron or steel to produce its own castings. For the small manufacturer this would prove of great assistance and advantage.

I have attempted in this paper to give the reader a rapid view over the great field in which the electric furnace is being used. If in some ways it is a fad just now, the time is not far distant when it will be a universal appliance, and by its manifold applications will add one more victory to the many already achieved by the indomitable and persevering scientist.

A FEW POINTS ON RAILROAD TERMINALS, WITH SPECIAL REFERENCE TO ROUNDHOUSES.

R. E. W. Hagarty, '07.

On account of the popularity of railroad engineering among School of Science men, I have thought that a few points on Railroad Terminals might be of interest. This article is intended to enlighten, in a general way, those whose experience may have been on a different class of engineering work. The subject is broad; necessarily the remarks will be limited, and will be almost entirely descriptive.

I wish first to deal briefly with the general lay-out of terminal yards, and then to discuss some accompanying structures. Of these, I wish to give special attention to the roundhouse, owing to its somewhat unique design.

In the general plan of yard lay-outs, the factor of prime importance is simplicity. By this is meant that as far as possible, without seriously increasing the cost of obtaining suitable ground, all tracks should be parallel, and have as little curvature as possible. The number of switches on the main line tracks should be minimized. The reasons for the foregoing are as follows:—First, a yard laid out with these ends in view, naturally facilitates the systematic and expeditious shunting and "spotting" of cars; second, and most important, a complicated system of tracks and switches increases the chance of delivering a fast train on to the wrong track and therefore adds to the probability of accident. Large terminal freight yards are divided into sections for receiving and classifying incoming cars and for "making up" outgoing trains. In such yards gravity, or a system of up and down grades, is m de use of to assist

in shunting, this type being known as a "gravity yard." The grade used in the gravity yard is about .333%; if much heavier, say .5% or more, the wear and tear on both brakes and brakesmen is considerable.

Examples of good terminal yards are those of the Canadian Pacific Railway, recently laid out in the west of Winnipeg; also the Montreal terminals. The Pennsylvania R. R. terminals at Philadelphia have been considered the ideal American model.

Of the structures in connection with terminal yards, one of the most important is the engine house with its attached repair shops, the two usually built together. They are used for housing locomotives when not in use, for cleaning them and making repairs. The older and somewhat less expensive form of engine house was a rectangular shed, built of timber or corrugated iron. In various ways it resembled the modern street car barn. The tracks were, in some cases, placed in the shed diagonally, thus economizing not only the ground space occupied by the house, but the amount of wall building. However, the objection to this form of engine house was that a large amount of ground was required for track approaches, and in large cities, where land is expensive, the additional cost was considerable. The usual modern type is a polygon-shaped structure built in circular form around a turntable, with tracks leading radially from the turntable into the shed portion. This is commonly known as a "roundhouse." Its chief advantage lies in the fact that only one approach track is needed, this track leading to the turntable. The space used for this purpose is therefore much less than is required in the case of the rectangular shed. But this advantage is to some extent counteracted by certain drawbacks worthy of notice. This turntable system renders it impossible for more than one engine to be taken out at a time; consequently, the roundhouse is a veritable fire trap, and when a number of engines are in the house at once there is the possibility of great loss to the road in the event of fire. Moreover, should the turntable break down, a serious blockade of engines might occur, and the traffic accommodation seriously impaired for several hours or even days. However, by care

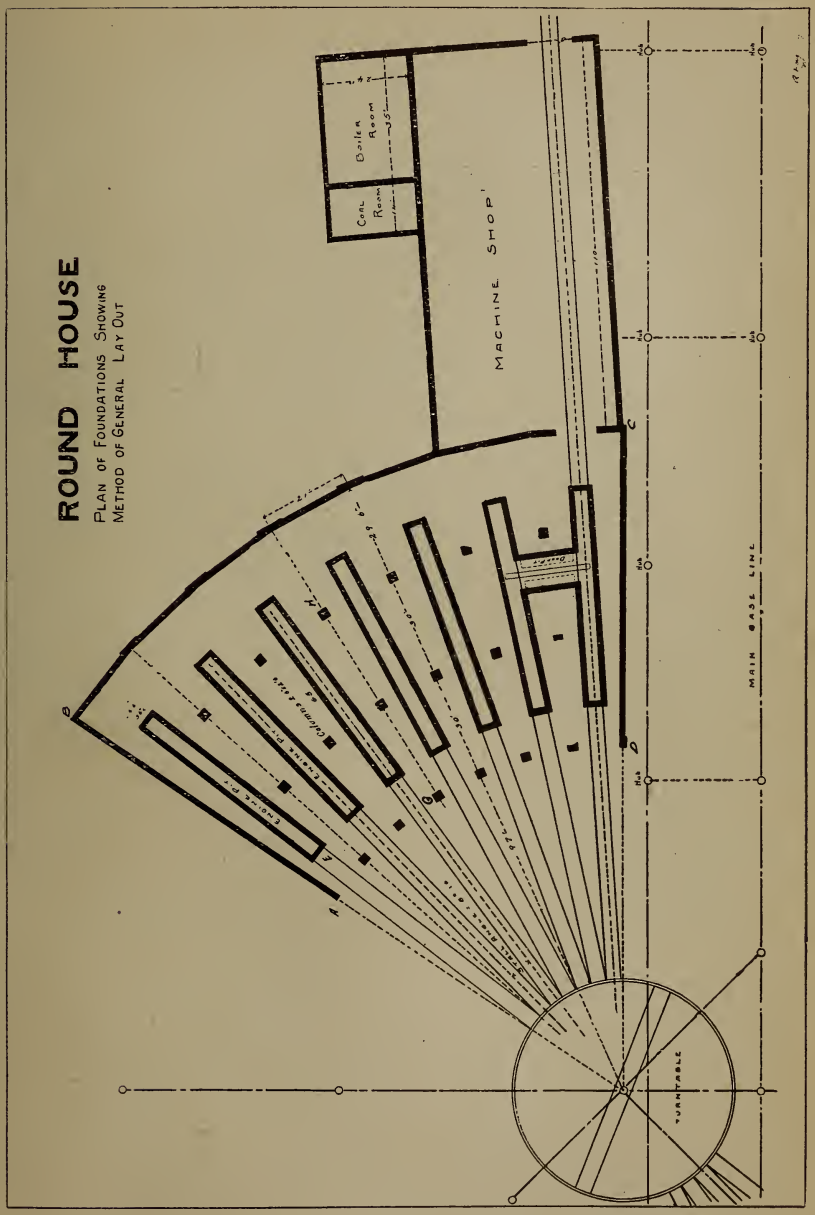
in the selection of a fireproof building material, and in securing solid turntable foundations, these disadvantages may be minimized. This fact, together with the natural tendency for one road to copy another, may account for the general adoption of the roundhouse. The structure may be built as a full circle, as is usually done on large, well established roads. The number of tracks radiating into the shed will, of course, depend on the size of the turntable and the track width. The larger the circumference of the turntable circle, the greater the number of tracks of a standard gauge which can be accommodated by this perimeter. But on small, new roads, first cost is an important practical consideration, and consequently roundhouses are usually built in the form of a segment of a circle, capable of extension. A typical foundation plan of such a structure is shown in the accompanying diagram.

I shall attempt to outline briefly the process of construction of a roundhouse as shown on the attached plan.

EXPLANATION OF THE DIAGRAM.

A B and C D are the end walls built on radial lines from the centre of the turntable. Their length is determined by that of the longest engine on the road. B C is the outside wall, and consists of a series of panels forming chords of a circle of which the centre of the turntable is the centre. E F is one of the seven or eight "stalls." The stall is simply the portion of the track on which the engine stands when in the roundhouse, and its centre line is also a radial.

G and H, etc., are columns to support roof. A D, the inner circle of the shed portion, is taken up almost entirely with doors, hinged on the columns and the extremities of the end walls. The track of one stall, extended, should lead directly into the machine shop, and, at the point where it enters the shop, there should be no curvature if it can be avoided. In case it is unavoidable, it is preferable to put in a sharp, and consequently a short, curve, as lengthy curves in a roundhouse are a waste of space.


ROUND HOUSE
PLAN OF FOUNDATIONS SHOWING METHOD OF GENERAL LAY OUT
MACHINE SHOP
BOILER ROOM
COAL ROOM
MAIN BASE LINE
TURNTABLE

Two of the most important considerations an engineer in charge of construction has to deal with are: 1, the selection of the exact location for the building, and, 2, the method of laying out the work on the ground. The roundhouse should be so situated as to admit of being close to the water tank, coal-chutes, etc. In case of building merely a segment to start with, care must be taken that the roundhouse, when extended in completion of the circle, will not interfere with the main-line track or any permanent structure. Railroad terminals are chosen preferably on flat and consequently very often low and unsolid ground. Hence foundations are an important consideration in choosing the exact site. In other words, the engineer's task in this connection is usually one of making the best of a bad bargain.

In regard to foundations, there are several points to be kept in mind. If the ground is low, a thorough system of off-take ditches should be first constructed. In case of muskeg, it will be necessary to drive piles. If rock is obtainable at an average depth of a few feet below the surface, it is advisable to build directly on the rock. However, uniformity of subsoil is most desirable, as uneven settling causes serious cracks to appear in the walls after construction. The entire clearance of rock is advisable unless rock can be obtained under the whole foundation.

The site selected, the details of lay-out next come in for consideration. Obviously the centre of the turntable is the first point to be selected, because from it points in almost any part of the lay-out may be determined by a system of angles and linear measurements. The first thing to be done by the engineer is to plant a substantial transit hub. This being established, the direction of one of the end walls, say C D, may be selected and used as a base line. By chaining a calculated distance (97′ in a specific case I have in mind), the inner extremity of this end wall may be located. Similarly the other extremity. Then by turning off a calculated angle (say 8° 16′) the direction of the centre line of the first stall is established, and any required points on this line may be found by chaining. Similarly the other stalls, points on the outside wall

and the position of the columns may be accurately located. Owing to the vital importance of the centre of the turntable, it is necessary to reference it thoroughly by a system of base-lines, so that it may be accurately replaced at any time during construction.

CONSTRUCTION OF ROUNDHOUSES.

In constructing roundhouses, the fire-proof qualities of the material should be kept in view. Formerly brick or stone or a combination of these was used; but latterly, on account of its cheapness and its absolutely fire-proof properties, reinforced concrete has been largely, almost exclusively, adopted. The walls of the structure consist of a six or eight-inch footing course three feet wide, imbedded a few feet below the surface of the ground and surmounted by an eighteen-inch wall up to the elevation of the base of rail, and above this a twelve-inch wall to the roof. The footing course is reinforced by strips of band-iron imbedded horizontally in the concrete near the bottom, to resist the tension produced by the lateral bending moment in the three-foot course. The columns supporting the roof are reinforced by four half-inch iron rods imbedded vertically in the columns, which are spanned at the tops by reinforced beams. The concrete used in these walls, columns, etc., is by certain specifications a mixture of five parts of gravel, three of sand, and one of Portland cement. Sometimes broken stone is used instead of gravel, in which case the fragments by specification should pass through a two-inch ring. The concrete, whether mixed mechanically or otherwise, should receive thorough and constant inspection, as a slight deficiency in the proportion of cement used might cause a serious failure.

I shall now briefly describe the other features of the roundhouse, such as engine-pits, drop-pits, roof, doors, lighting, ventilation and turntable. The engine-pits are shallow pits between the rails of the stalls, the width being governed by the track-gauge. They are used for making light repairs to locomotives, and also for washing. The wash water, and, in winter, the melted ice and snow from the engine, drips into the pits and is thence carried off by

drains. A drop-pit is placed at right angles to one of the engine pits and is used for removing axles or other heavy portions of the machinery.

The roof of an engine-house may be covered with slate or tarred felt, but of late the use of asbestos roof-boards has come into vogue. Other materials are corroded by the sulphurous gases from the engine smoke. The roof may be supported in two ways: first, by a roof-truss; second, by columns. The roof-truss method involves a considerable amount of extra space to be heated in winter. By the use of columns it is possible to obtain a comparatively flat roof, and therefore less space to be heated. The columns, while serving this purpose, in no way interfere with the operation of the roundhouse. Hence this form of roof support is economically preferable.

The doors, which are practically always swung, are sometimes designed with rounded tops. The justification of this design is entirely aesthetical, but the plain, square-topped doors are less expensive, and more in keeping with the unpretentious environments that necessarily prevail.

The interior should be well lighted. Hence the window space should be as large as possible, lights being inserted in the outside wall, and, as transoms, over the doors. For night lighting, electricity should be used, if possible, to decrease the danger of fire.

For ventilation, each stall is provided with a smoke jack. This is merely a pipe with a bell-shaped mouth so placed as to cover the locomotive smoke-stack and carry off the smoke through the roof.

One of the most interesting parts of the roundhouse system is the turntable. This is usually a steel plate girder, revolving on a pivot which, during revolution, carries the whole weight of locomotive and girder. The importance of the pivot foundation is obvious, and it is desirable, if at all possible, that these foundations should be placed on rock, a feature which in case only a small amount of rock is available, should be taken into account under the head of location at the outset. The diameter of the turntable is of course governed by the longest engine on the road. When properly balanced, the

turntable, with the engine, is usually revolved by hand, one man being able to push the whole weight. In some cases a small electric motor is used. As the engine is leaving the turntable, the poise is of course disturbed, and the end of the girder drops a couple of inches, where it is temporarily supported by a circular rail.

WATER TANK AND COAL CHUTES.

Other terminal structures related to the roundhouse in importance and situation are the water tank and the coaling station, the latter being technically known as "coal chutes." The details for these have become standardized, so there remains for the engineer in charge of construction only the fulfilment of those special conditions peculiar to any specific case.

The source of water supply, of course, first decides the location of the water tank. This should be conveniently near the roundhouse, coal chutes, ash pits, etc. If the ground is soft, piling may be necessary; the required number of piles may be estimated by computing the weight of the structure obtained from the "bill of material" by a reference to a Carnegie or similar handbook, adding the weight of water and allowing about four tons of the total weight to be carried by each pile. The piles should be arranged symmetrically under each post of the structure supporting the tank. They should be driven till the final drop of a two-ton hammer falling through 20 feet buries the pile not more than an inch or two. The piles may be capped by timber or by concrete piers, the head of the pile projecting into the concrete about one foot. The substructure supporting the tank is of timber or of light structural steel.

It is important to notice that where winter is severe precautions must be taken to prevent freezing. The simplest and most effective method of accomplishing this result is to "jacket" the tank or to surround it by a wall of two thicknesses of Manitoba siding, separated by a six-inch air space, which is found to have considerable frost-proof qualities. In addition, steam pipes are usually placed inside the tank. An average railway water tank has a capacity of about 50,000 imperial gallons.

A simple form of coal chute is an elevated shed some 30 feet wide, and of length to suit the required capacity of several hundred tons. Along the side of this shed a through track is laid, close enough to admit of coal being fed to locomotives by means of apron doors. This track should be open at both ends, that is, connected at each end with a main-line or main-line feeder track, so that more than one locomotive may take coal simultaneously. The coal chute is approached by a trestle with a grade inclination not exceeding four per cent. A long period of development in railway engineering has caused the designs and the methods of practice to become largely stereotyped. However, in the preceding remarks I have endeavored to enumerate such points as in themselves may seem to be important; still, experience has shown that lack of foresight in regard to such points as these might easily cause, and has caused, serious defects in the laying out and the construction of railroad terminals.

MANUFACTURE AND PROPERTIES OF WROUGHT PIPE.

F. N. Speller, B.A.Sc.

Prior to 1886 all welded tubes and pipe were made of wrought iron. In that year a small quantity of pipe was successfully made of soft steel, at the Riverside Works of the National Tube Company, Wheeling, W.Va., but the successful development of soft welding steel has really been accomplished only during the past ten years. The manufacture of this grade of steel is now a special branch of the steel industry, furnishing a material having many advantages for mechanical welding.

At the present time about 25% of the welded tubes and pipe are made of wrought iron. The proportion has been growing constantly less since the introduction of steel. Two principal grades of iron are now being made:—(1) charcoal iron for boiler tubes and (2) common wrought iron made by the well known puddling process.

The manufacture of charcoal iron is one of the oldest and most interesting metallurgical processes. The first step in refining is accomplished in the refinery or run out fire, as it is called. Charcoal pig iron contains about 95% of metallic iron, the remaining 5% being carbon, silicon, manganese, phosphorus and sulphur. In the "refinery" the silicon and manganese are practically eliminated with about 50% of the phosphorus. This furnace consists of a rectangular hearth with water cooled sides, over which is a hood and stack. The hearth is 15 inches deep below the tuyere line. Rotary blowers supply blast at a pressure of 2 lbs. per square inch, which impinges on the molten iron in the hearth through inclined tuyeres on each side; the silicon and manganese and some of the iron

oxidize forming a slag which combines with suitable cinders added with the charge and acts as a carrier for the removal of a certain amount of the phosphorus and sulphur. The refined metal is run out into a chill mold, broken up when cold, and piled awaiting the next operation, which is conducted in the "Knobbling Fire." This is a slightly modified form of the old Catalan Forge, which in the dawn of the iron-making era was used to produce wrought iron direct from the ore. The refinery metal is reheated by waste heat from a previous charge in lots of 400 lbs., and in turn is drawn down into the forge and heated by side blast in a bed of charcoal. The arrangement is very primitive and has not seen much improvement since the days when the grandfathers of the present knobblers worked their forges in Sweden or Wales.

The metal melts and drop by drop trickles down through the charcoal, losing its carbon under the highly oxidizing environment, and forming a strongly oxidizing and basic cinder which removes a considerable part of the remaining sulphur and phosphorus contents. Additions of cinder from previous heats help the reduction and economize iron. At the finish the knobbler has a pasty lump of crystals of iron roughly welded together and intermixed with cinder. The last operation consists in hammering this lump so as to remove the cinder as completely as possible. After the first hammering, the bloom is reheated and again placed under the steam hammer, from whence it is taken to the break down mill, where it is rolled to a bar one inch thick. These bars are cut up and piled four high, reheated, and rolled in a continuous mill to a plate of the required gauge and width with scarfed edges. This puts the iron in shape for the tube and pipe departments. The process of refining at each stage of the operation can be best illustrated by average analyses of the material given below:—

	Total Carbon %	Mang. %	Silicon %	Phos. %	Sulp. %	Oxides & Cinder %
Pig Iron.....	3.85	.98	.94	.086	.025	_____
Refinery Mtl...	3.50 (comb)	Trace	.21	.070	.024	_____
Finished Plate.	Trace	Trace	.014	.024	.014	.92

The second and coarser grade of wrought iron required for the manufacture of pipe is made by the puddling process, which need not be touched on here. Practically no improvement has been made in this process since the introduction of cheap steel. The grade of iron thus made for welded pipe contains on the average:

Silicon	.100%
Phosphorus	.220%
Sulphur	.020%
Manganese	Trace
Carbon	Trace
Oxides and slag	2%.

The manual labor connected with the making of all grades of wrought iron is severe and the skill required quite considerable. Owing to the inducements in other fields to-day it is difficult to recruit the dwindling ranks of old time operators with younger men, since with the intelligence required to make a good knobbler or puddler, a man can now-a-days make more money at other work and lead a less strenuous life. These processes have served their purpose well and will doubtless hold their own for a while for special purposes, but the natural course of evolution seems to point to the passing of such methods, especially as modern practice improves the quality of steel, which now competes with iron in all lines. Wrought iron is hard to regulate in quality, principally on account of (1) irregularities in composition of pig iron used; (2) the small quantity made in one heat; (3) the personal attention and skill required on the part of the puddler, and the large personal equation thereby introduced. The iron of to-day is rendered still more unreliable by the practice of some makers who intermix steel scrap of uncertain composition, thereby, of course, lessening the cost of manufacture.

By carrying the Bessemer process to the limit of refining, and treating the metal so as to give the best results in welding, a refined iron is produced practically uniform in quality, which will roll into a plate with a true edge—a very desirable condition for good

results in the pipe mills. To obtain the best results it is necessary to manufacture "pipe steel" on a scale sufficiently large to take the full capacity of a steel plant. Under these conditions it is probably safe to say that uniformity of product is obtained unequalled in any other class of steel manufactured on this scale.

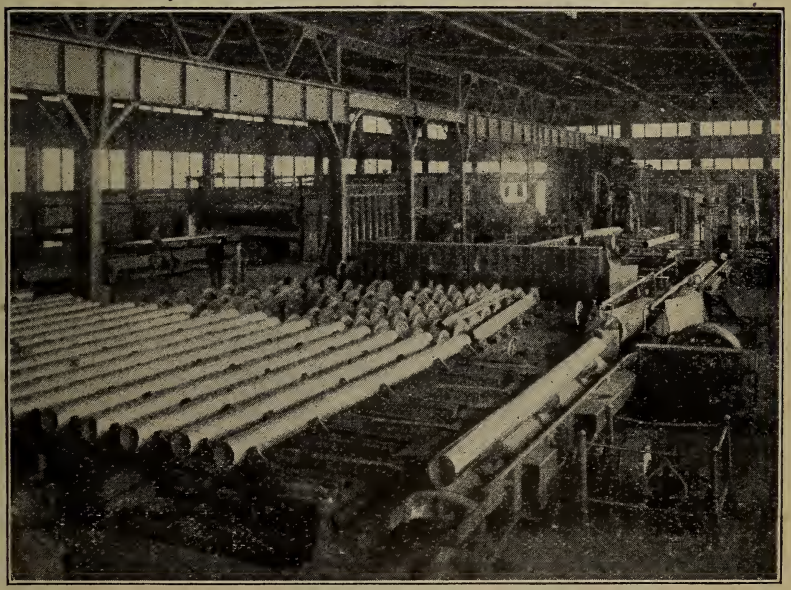
A smaller proportion of pipe and steel is made by the Basic Open Hearth process, but the easy control and continuous supply of uniformly very low carbon steel which can be had from a Bessemer plant running in conjunction with pipe and tube mills, and the

MODERN LAP WELD MILL FOR LARGER PIPE—CHARGING END.

satisfactory nature of the product, have caused the Bessemer process to become firmly established for this class of work. The higher phosphorus and sulphur contents of Bessemer steel are no objection in welding pipe where the quantity of metal used is so greatly in excess of what strength requires, and moreover these elements become a necessity if the pipe is to be tolerably easy to thread. Pipe steel welds with greater ease and with much less loss on account of blisters and laminations than wrought iron.

GROWTH OF TUBE AND PIPE INDUSTRY.

The production of welded tubes and pipe has almost doubled in tonnage since 1899. During this period the process of making pipe steel and mechanical welding by the butt and lap weld process has been much improved, giving a more uniform product and at the same time reducing costs all round. The introduction of pipe steel has apparently had somewhat the same influence in expanding the



FINISHING SIDE OF WELDING FURNACE—COOLING TABLES IN FOREGROUND.

field of use for tubular goods as the advent of structural steel exercised on the production of materials of construction, formerly made of wrought iron. In 1905 the production of tubular goods in the United States (1,435,995 tons) nearly equalled that of rolled structural shapes (1,660,519 tons) not including plate. The production for 1906 promises to reach 1,700,000 tons.

The generally good welding quality of wrought iron enabled it to maintain its position as the metal for the manufacture of pipe

years after it had been displaced by steel as a material for general engineering construction. In 1890 about 3% of the welded pipe was made of steel; in 1905 this had increased to 70% and it is estimated that steel pipe will constitute 80% of the output for 1906. Besides the general use of pipe in steam, water, gas and oil lines, which consumes the larger part of the tonnage, increased amounts are being used for trolley poles, electric conduits, bedstead construction and for other special purposes.

Among the special uses to which steel pipe lends itself, the catenary system of trolley suspension might be referred to. Large quantities of the small sizes of extra strong pipe are used in making the light triangular frames from which the live wire is suspended in high speed electric railroad construction. The joints are either threaded, or flattened and pinned together. Steel pipe combines a maximum strength for its weight, very desirable for such work. Wherever pipe has to be bent or worked either hot or cold the modern material has a decided advantage.

In the California field a quantity of steel pipe has been rifled, the object being to cause the viscous oil intermixed with a small per cent. of water to whirl as it moves rapidly through the pipe. When a sufficient velocity is attained, a layer of water flows between the oil and the pipe, reducing the friction in the line.

It has been found quite practicable to roll spiral corrugations 3-32-in. deep in the surface of the pipe by means of six wheels set equidistant around the circumference and slightly inclined to the axis of the pipe, so as to make a complete revolution on the surface of the pipe every 10 feet. The material appears to stand this treatment cold without difficulty.

It might be well to refer here to the heat treatment necessary to anneal pipe steel. The heat required to weld iron or steel produces a larger grain in the metal. For most purposes this does no harm and steel pipe unannealed will stand remarkably severe cold bending without fracture, having an elongation of 20 to 24% in 8 ins. in this state, but where the pipe has to be worked hot it is

advantageous to first heat it to a full orange (above the critical range of 900 degrees C.) for a few minutes and then allow the metal to cool slowly in the air. This will completely remove all possible effect of overheating, by refining the grain, and will enable the metal to be worked without danger from red shortness. Tubes or pipe will stand more cold working if so annealed. The ends of boiler tubes should be given this treatment before being expanded and rolled into the flue sheet.

PRINCIPAL PHYSICAL CHARACTERISTICS OF PIPE MATERIALS.

From the manufacturing standpoint, the superior welding quality, uniformity and lower cost of pipe steel are the determining qualities. The tensile strength of pipe steel pulled transversely is about double that of wrought iron, hence the welded seam might be expected to be proportionately strong. This has been shown to be true by experiments on 2-in. butt welded pipe. The average strength of the weld was thus found to be 70 to 72% of the strength of the metal transversely in each case, and the steel weld proved to be twice as strong as the wrought iron. Bursting tests on wrought iron and steel butt welded pipe confirm these conclusions. The strength of the seam was compared by twisting pieces about 8 feet long until they failed. The following results were obtained on three sizes of standard pipe:

TABLE I.

TWISTING TESTS ON BUTT-WELDED PIPE.

SUMMARY.

Size.	Material.	Make.	Wt. Per Ft.—lbs.	Variation from Card Wt. %	Max. Pull on 3 Foot Lever—Lbs.			Number of Turns in 6 Feet	% Failed in Weld.
					Low.	High.	Average.		
½ in.	Steel	N. T. Co.	.816	—2.2	90	120	109	15	0
"	Iron		.803	—4.2	40	98	68½	4½	73
"	Iron		.792	—5.2	20	113	81	5¾	66
"	Iron		.842	+0.6	50	85	65	2½	100
¾ in.	Steel	N. T. Co.	1.082	—2.9	160	185	172	8	13
"	Iron		1.097	—1.6	140	160	154	6⅕	33
"	Iron		1.127	+1.0	80	176	136	3½	66
"	Iron		1.104	—1.0	50	160	107	2½	90
1 in.	Steel	N. T. Co.	1.658	—0.7	180	340	300	5½	13
"	Iron		1.593	—4.4	220	292	256	4½	46
"	Iron		1.616	—3.1	170	300	250	3⅓	33
"	Iron		1.620	—2.8	100	320	258	3¾	66

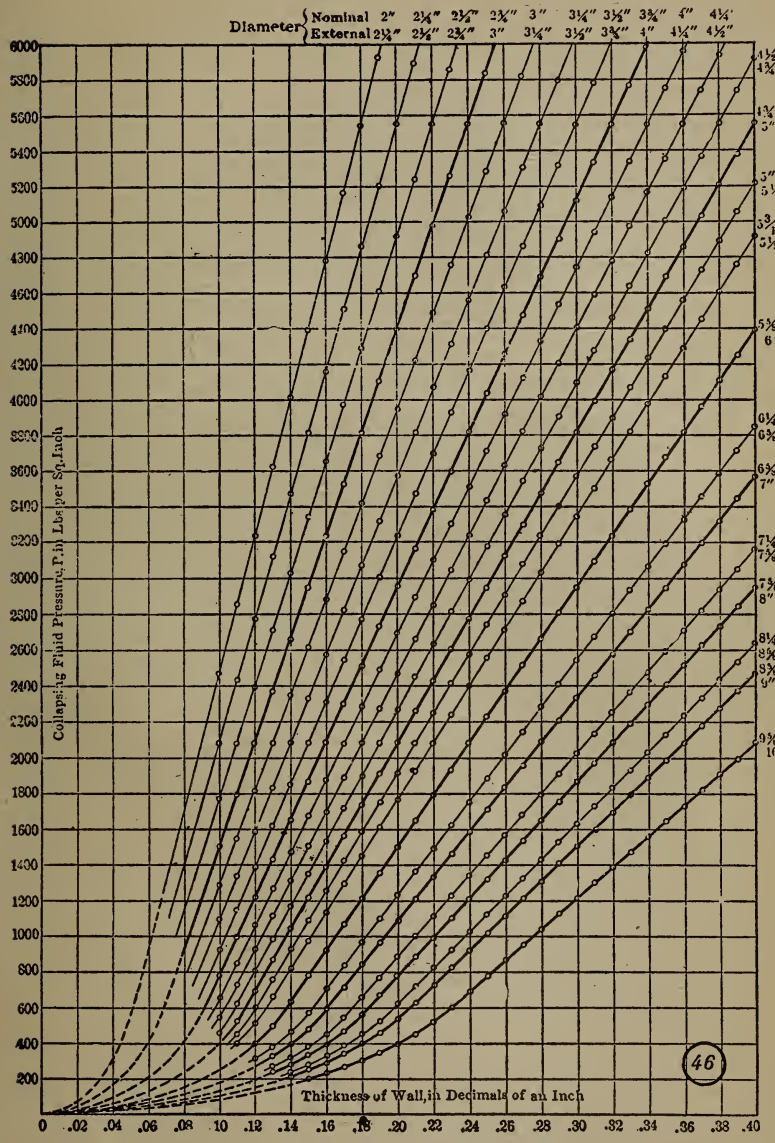


Diagram of collapsing pressures

Pipe steel finishes with a smoother surface than wrought iron, which for some purposes is very desirable.

A list of the physical properties of steel pipe would not be complete without referring to the exhaustive series of tests made on the National Tube Company's lap weld steel pipe by Prof. R. T. Stewart, to determine the collapsing pressures. This work employed from one to six men for four years and involved the collapsing of nearly four hundred pieces of pipe, 3 ins. to 10 ins. in diameter, mostly 20 feet in length. The details may be had by reference to Prof. Stewart's papers in Trans. of Am. Soc. of M. E. for this year.

THREADING PIPE.

Steel pipe has been objected to by some, chiefly on account of the fact that it is somewhat harder to thread with the poor dies with which many threading shops are equipped, and which are too commonly sold to the trade. It is to be expected that a practically pure iron will offer more resistance to a blunt and improperly shaped die, than will a metal like puddled iron, in which are intermixed layers and strings of cinder amounting to 2 or 3%. The power required to thread with a die, is approximately proportional to the tenacity of the metal. By properly grinding the chasers and providing relief so that the heel does not drag, the difference in power required to thread iron and steel disappears and much better results are obtained with less wear and tear on the dies.

Considerable unnecessary trouble has been caused through die makers not recognizing the importance of these points, especially to the small operator depending on hand power. It may seem to some a rather elementary point to emphasize before this Society, but we even now occasionally hear from large well-equipped shops up-to-date with nearly all modern improvements, yet ten or fifteen years behind in their die equipment. It is not surprising that many should have preferred wrought iron where much threading and cutting has to be done, as it is only within the past year or two that the much needed improvement has been introduced by certain makers of standard hand dies.

CORROSION OF IRON AND STEEL.

This is a question which has brought forth many opinions, but in most cases with little practical evidence. After investigating closely many cases which have come under my observation during the past two years, where the two materials were put in service together and subject to the same conditions, I have never yet found any decided difference. The impression which exists in some minds that wrought iron pipe is much superior to steel in durability, may have originated in comparisons on pipe made years ago when the practice of making sound low carbon steel was probably not so well understood as it is to-day, or it may have been a mistaken identity, for we frequently find iron mistaken for steel, especially if it happens for some cause to be pitted, but in most cases the idea has apparently been spread by hearsay and accepted without investigation.

In view of the inherent differences between iron and steel made for various uses, it would seem safer to compare each class by itself, i.e., wire, sheet, pipe, etc., each under the conditions of service to which it is subject.

The essential conditions of corrosion, air, water and carbonic acid, are easily duplicated in the laboratory, but in practice corrosion is accelerated by presence of sulphurous and other solutions, stray electric currents, heat and numerous other influences difficult to trace.

It will be conceded that such conditions tending to seriously affect corrosion, are rapidly on the increase, especially in and near the great centres of population. Hence we should be slow to draw conclusions from the statement that steel does not last now-a-days as it did 15 or 20 years ago. Whatever the relative standing of the two materials was years ago (and opinions differ widely), what we are more concerned with is, how do they stand to-day, and how can they be best protected from corrosion? Laboratory results, while open to criticism, as not truly representing actual conditions in the field, are valuable as indicating the relative standing of a number of samples under conditions known to be uniform—some-

AVERAGE RESULTS OF RECENT COMPARATIVE TESTS ON CORROSION OF WROUGHT IRON AND PIPE STEEL.

(*Losses* per unit of surface exposed compared with Puddled Iron as 100)

No. 1	Conditions of Test.	Authority.	Duration of Test.	Charcoal Iron.	Puddled Iron.	Pipe Steel	Test Standard
No. 2	Aerated distilled water. Normal Temp.	U. S. Navy Dept.	64 Weeks	100		94.5	1901
No. 3	Sea water Normal Temp.	H. M. Howe	2 Years		100	119	1897
No. 4	Aerated Brine	Lab'ry. Nat'l Tube	6 Months		100	106	1904
No. 5	Aerated water 180 deg. F.	"	3 Months		100	90.6	1905
No. 6	Aerated brine 180 deg. F.	"	3 Months	80	100	75.3	1906
No 7	Aerated sea water 180 deg. F.	F. Howe	3 Months	94.4	100	94.2	1906

thing difficult to be sure of in service tests. The writer has in his tests lately used a 5% hot solution of brine through which a continuous flow of air is pumped. One reason for adopting this solution is that a number of tests are on record which indicate that steel in general seems to be somewhat more susceptible to this environment than wrought iron, and further that the loss is quite considerable in a reasonable time (about 1-10 gram. per sq. in. per month). Some averages of a number of results on pipe material are given herewith, comparison being made with good wrought iron as a standard.

There are two possible ways of protecting steel: 1st, by use of efficient protective coatings; 2nd, by treatment of the metal in the course of manufacture. Experiments have been carried on by the writer for some time at the works of the National Tube Company, with the object of increasing the durability of pipe steel. As a first step in this direction a process has been developed which after a year and a half's trial has given results showing a decided benefit to the steel, especially in the uniformity with which it corrodes. The treatment consists in a mechanical working or kneading of the metal which tends to produce greater uniformity and improve the quality and texture of the steel. Doubtless much of the steel does not need this treatment, but in such cases it does no harm, and on the whole raises the average standard of the output. Tests marked Nos. 5, 6 and 7 were made on this steel.

It has been recognized that service tests must be made before any certain conclusion can be reached. A number of such tests have been made on this steel pipe in sulphurous air, salt water and mine water during the past year, precautions being taken to have an equal number of pieces of "genuine" wrought iron pipe alongside under the same conditions. The results so far have shown the steel so treated without exception to be at least the equal and generally decidedly superior to wrought iron.

The latter portion of this paper, dealing with the characteristics of pipe material and its corrosion, was read before the Engineering Society of Western Pennsylvania, in November, 1906.

CONTINUOUS BEAMS.

A. W. Connor, B.A., C.E.

Problems in continuous beams are much more frequently met with in the design of structures of reinforced concrete than of steel. For concrete beams are, from the nature of their construction, rendered continuous over their supports. With the rapid growth of concrete construction, the study of the action of the continuous beam is in consequence of much more general interest now than formerly, when it was very generally limited to the case of swing or cantilever bridges. It is not proposed however in this brief paper to discuss the general theory, but to give a few applications of it to problems on which the author was unable to find any reference in the standard works. It is believed that these results might be of interest to your society.

No doubt the lack of published information and the difficulty of solving the general equations has led to rule of thumb methods of designing continuous beams, or to the entire neglect of the effect of the continuity. The continuous beam is more economical than the discontinuous beam, and the failure to treat it as continuous has not only been wasteful in material, but has marred many buildings by the excessive deflection and cracking of the floors. As far as the reputation of the designer is concerned, such a floor is as fatal as an actual collapse of the same. The subject is then of sufficient importance to merit a careful study of the conditions of stress in all parts of the beam.

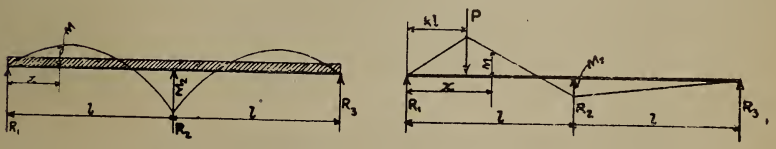
The fundamental theory, by means of which any problem in continuous beams may be solved, was first published by Clapeyron in 1857, and with subsequent additions by Weyrauch and Merriman, is known as the "Equation of Three Moments." It is based on the elastic theory and on the assumption of a uniform moment of inertia throughout the length of the beam. It is also assumed

that the beam is freely supported, not fixed, and that the supports are on a level, or to be more exact, that in its unstrained condition it rests freely on all its supports.

There is an erroneous impression in some quarters that the continuity of action in concrete beams in a building depends on the rigidity of the columns. Such rigidity tends to give the condition of a beam fixed at the ends. In practice no doubt the actual condition of the beam is between a continuous beam freely supported and one fixed at the supports. In other words the inclination of the beam at the supports lies between that given for continuity and the horizontal position given by fixing the ends. It will be instructive to compare the moments and shears of a beam continuous over several supports and one fixed at the ends.

Below will be found some results for beams continuous over two or three equal spans of length l. From the equations given it is an easy matter to determine all the other conditions of stress.

TWO EQUAL SPANS.



1. Uniformly distributed load p per foot. The maximum positive moment at any point in either span occurs when that span only is loaded. This loading will also cause the maximum negative moments in the far end of the other span.

The moment curve is a parabola on the loaded span, and a right line on the other span

$$\text{Max. Mom.} = .0957\ pl^2 \text{ when } x = \frac{7}{16}\ l$$

$$M_2 = -\frac{1}{16}\ pl^2$$

If both spans were loaded $M_2 = -\frac{1}{8}\ pl^2$ which gives the maximum negative moment. Since the loading is symmetrical, the beam

is horizontal at the centre, and is then in the same condition as a beam fixed at one end and supported at the other, and the moment at the fixed support has the same value.

The negative reaction, $R_3 = -\frac{1}{16} pl$ due to the left span only being loaded will be neutralized by continuing the loading .426 l past the centre support.

2. Concentrated load P at distance kl

$$R_1 = \frac{P}{4}(4 - 5k + k^3).$$

The maximum positive moment will be under the load.

$$M = \frac{P}{4}(4k - 5k^2 + k^4)\, l$$

This will have a maximum value, $M = .2074\ Pl$ when $k = .433$.

The maximum negative moment will be at the centre pier, $M_2 = -\frac{P}{4}(k - k^3)\, l$, and will have a maximum value of $M_2 = -.0962\ Pl$ when $k = .577$.

3. Two symmetrical loads of P at distance kl from each end.

$$R_1 = \frac{P}{2}(2 - 3k + k^3)$$

The max. pos. moment is under the load,

$$M = \frac{P}{2}(2k - 3k^2 + k^4)\, l.$$

It will have a maximum value, $M = .174\ Pl$ when $k = .366$.

The max. neg. mom. will be at the centre pier, $M_2 = -\frac{P}{2}\left(k - k^3\right)l$ and will have a max. value, $M_2 = -.1925\ Pl$ when $k = .577$.

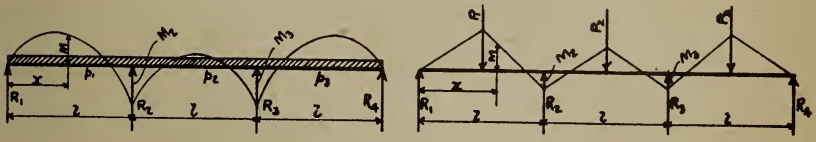
As the moment is always negative at the centre pier for any loading, it was to be expected that this latter value would be twice that given for a single concentrated load as in case 2. It will also be noted that, as the loads are symmetrical, the values given above are the same as for a beam fixed at one end and supported at the

other. When the load is at the centre of the spans (or at the centre of a beam fixed at one end and supported at the other) then $M = \frac{5}{32} Pl$. Some books give this as $\frac{3}{16} Pl$, which is clearly erroneous. The negative moment at the fixed end is however $= -\frac{3}{16} Pl$.

THREE EQUAL SPANS.

l = length of each span.

M_2 and M_3 = bending moments at intermediate supports.



4. Uniform loads p_1, p_2 and p_3, per foot on spans 1, 2 and 3 respectively.

$$M_2 = -\frac{1}{60} l^2 (4\ p_1 + 3\ p_2 - p_3)$$

$$M_3 = -\frac{1}{60} l^2 (-\ p_1 + 3\ p_2 + 4\ p_3)$$

If the loading is uniform throughout $M_2 = M_3 = -\frac{1}{10} pl^2$. The other moments and reactions are easily determined from these equations.

5. Concentrated loads P_1, P_2 and P_3 at the centre of spans 1, 2 and 3 respectively.

$$M_2 = -\frac{1}{40} l (4\ P_1 + 3\ P_2 - P_3)$$

$$M_3 = -\frac{1}{40} l (-\ P_1 + 3\ P_2 + 4\ P_3)$$

If the loads are all equal, $M_2 = M_3 = -\frac{3}{20} Pl$. These moments are thus seen to be 50% greater than if the same load in each panel were uniformly distributed.

6. Two concentrated loads each of P_1 P_2 and P_3 placed at the third points of spans 1, 2 and 3 respectively.

$$M_2 = -\frac{2}{45} l\,(4\,P_1 + 3\,P_2 - P_3)$$

$$M_3 = -\frac{2}{45} l\,(-P_1 + 3\,P_2 + 4\,P_3)$$

These moments are thus seen to be one-third greater than if the same loads in each span were uniformly distributed.

The above are some of the problems more frequently met with in practice. The subject might be considerably extended if desired. Nothing has been given on the question of the deflections in continuous beams, an important subject that might well merit further consideration.

OBITUARY NOTICES.

GEORGE ALEXANDER BREBNER.

George Alexander Brebner, whose death occurred at Schenectady, on February 21st, this year, was born in Sarnia, on January 1st, 1875. In 1891, after the completion of his high school training, which was taken in his native town, he entered the Faculty of Arts in the Provincial University and completed successfully the first year in the following spring. In October, 1902, he registered as a student at the School of Practical Science, and was graduated in the spring of 1905. While a student, his vacations were spent with the Blaikie Foundry Co., Sarnia, the Peterson Machinery Company, Sarnia, and the McKee and Marwick Company, Petrolea, with whom he remained two years after graduation. In August, 1907, he entered the Students' course of the General Electrical Company at Schenectady, N.Y. In this work he showed marked ability, and during the Spanish-American war was specially employed on the testing of search lights for the War Department of the Federal Government. Afterwards he was transferred to the switchboard department, and for a number of years was chief estimator, and practically head of that branch of this Company's operations. In October, 1906, he was promoted to the power and mining division, where the estimating of the cost of power equipments, many of them of large magnitude, was his special work. Shortly before his death, he had completed an estimate on the cost of a gigantic electrical installation for what will shortly be one of the manufacturing centres of the Illinois Steel Corporation. Similar undertakings had recently occupied his attention in Minneapolis and St. Paul.

Brebner had shown conspicuous aptitude for electrical engineering, a profession in which his abilities and industry had already secured him very responsible positions. His fatal illness, which lasted only a week, was the result of an accident.

JOSEPH P. BELLISLE.

Early last May the students of the School of Practical Science were shocked to hear of the death of Joseph P. Bellisle, one of the most promising graduates of the class '06. He had been engaged as one of a survey party in New Ontario and left shortly after examinations to begin the summer's work. The party had gone up the Montreal river and were almost at the scene of their labors when the canoe capsized in a rapids, and the deceased, although a strong swimmer, could not endure the icy waters, and was drowned.

Mr. Bellisle was born at Georgetown, and received his early education there. He taught school a year and a half and then entered the employ of the Toronto Street Railway. He entered the School in the fall of 1903 and took a course in Mining Engineering, graduating in 1906. He was called away before he knew of his success at the final examinations.

The deceased was one of the best known men of his year. His indomitable pluck and perseverance made his undertakings successful, and no doubt had he been spared he would have made a name for himself. His genial disposition, good fellowship and generosity endeared him to all his acquaintances.

J. CAMERON PAULIN.

J. Cameron Paulin was born at Arthur, Ont., March 7th, 1886, and was the youngest son of William Paulin, a retired farmer of that vicinity.

His preparatory education was received at Arthur High School, and after completing his senior leaving, he entered, in the fall of 1905, the Faculty of Applied Science in the department of Mining Engineering.

The vacation of 1906 was spent as Mr. T. B. Speight's assistant on base line and meridian work, in New Ontario, and after a successful summer he returned strong and hardy for his second year at the School.

Possessing a fine physique and robust health, he was an enthusiastic devotee of outdoor athletics, and in the fall sports had always been a vigorous participant.

On the afternoon of October 3rd, during Rugby practice, he received a fatal injury in the skull, which resulted in a cerebral hemorrhage. He was carried to the Kappa Alpha chapter house, where medical attendance was summoned. In the evening it was perceived that complications had set in and he was removed to the hospital, where he expired a few moments after his arrival. The body was taken home to Arthur for interment.

Cameron Paulin possessed extraordinary courage and ability, and the breadth of his maturing character won for him the respect and love of all who knew him.

FRED. CODE.

The late Mr. Fred. Code, whose death through typhoid fever occurred at Smith's Falls, on October 29th, 1906, was the son of the late Wm. Code, of North Elmsley, and was at the time of his death just thirty years of age.

Having completed his high school course at Smith's Falls in 1894, he taught school at Roseville for a number of years, resigning in 1901, to enter the Civil Engineering Course in the School of Practical Science. He graduated in 1904, and returned in the autumn of the same year to take the post-graduate work in Astronomy, which he completed with honors the following spring. He was shortly afterwards appointed town engineer of Smith's Falls, which position he filled in a capable and faithful manner until the time of his fatal illness.

Needless to say, the taking away of one who in early manhood gave promise of such a brilliant and useful future, has occasioned general regret among a wide circle of friends. Of a studious and retiring nature, exemplary habits and possessing an upright and honorable character, he won the respect not only of intimate friends but of all with whom his business brought him in touch. He is survived by a widowed mother, four sisters and four brothers, one of whom, Mr. S. B. Code, was a class mate of the deceased.

W. J. BOWERS.

The unexpected death of Mr. W. J. Bowers in December, '06, came as a shock to a large circle of friends and acquaintances. Of unusually robust constitution, Mr. Bowers would have been considered particularly capable of resisting the dreaded fever which he had contracted, but the adversary proved the stronger and death came after a few short weeks of illness.

Mr. Bowers was one of the out-going class of 1901, and prior to his student days had been employed for three years with the Bell Telephone Company in Toronto. After completing his work at the School of Science, he spent three years with Mr. Willis Chipman, Civil and Sanitary Engineer. From 1904 until the time of his death, he was employed with Mr. John Galt on Municipal Engineering, chiefly, his position being that of chief assistant of the eastern work. In the Engineers' Club, of Toronto, Bowers had always taken an active interest, and had for some time previous to his death filled with every satisfaction the position of Treasurer. This work brought him in contact with the members of the profession in the Toronto district, and his geniality and good fellowship were proverbial with an extended and constantly extending circle. He is survived by a widow and three children, who have the sympathy of the community in their bereavement.

TREASURER'S REPORT.

Toronto, March 26th, 1907.

MR. PRESIDENT:—

I beg leave to submit the following report for the year ending March 27th, 1907:—

To balance on hand	$ 485	56
" amount of life members' fees	42	00
" amount of annual fees	2	00
" library proceeds	1,410	00
" receipts from advertising	225	25
" receipts from sale of pamphlet		50
" Government grant	75	00
" balance from dinner		44
" amount from old account	66	44
	$2,307	19

By amount of publishing pamphlet No. 19	$ 406	47
" " expenses incurred by old executive	41	36
" " printing account	74	28
" " paper and supplies	1,058	30
" " commission, discount and postage	82	98
" " pin	2	25
" " customs and freight	10	51
" " representatives' expenses	76	00
" " editor's salary	50	00
" " librarian's salary	50	00
" " photos, etc.	18	40

By amount present to Mr. Loudon		$	25 00
" "	typewriting		11 55
" "	flowers and funeral expenses		28 35
" "	refund on life membership		1 00
" "	election expenses		57 25
" "	Students' Parliament		15 00
" "	Engineering meeting expenses		20 00
" "	balance in bank		278 49
			$2,307 19

RESOURCES.

Amount due from Mr. Laing, fees	$	468 75
Other outstanding debts		146 08
Supplies on hand		451 03
Cash on hand		278 49
Total	$	1,344 35

G. E. QUANCE,
Treasurer.

AUDITORS' REPORT.

We have this day examined the books of the Treasurer of the Engineering Society and find them correct.

H. V. MAYNARD,
J. MCGOWAN, } Auditors.

Toronto, March 26th, 1907.

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